Corps of Engineers Northwestern Division
North Pacific
Portland, Oregon

2000

CORPS OF ENGINEERS DISSOLVED GAS MONITORING

COLUMBIA RIVER BASIN

February 2001

Including Material Provided by:

Portland District-US Geological Survey
Engineering Research and Development Center
Walla Walla District

Water Quality Team
Reservoir Control Center, Water Management Division

EXECUTIVE SUMMARY

This Annual Dissolved Gas Monitoring Program Report for 2000 was prepared with a new format based on internal Corps review comments and on requests from the National Marine Fisheries Service Regional Forum Water Quality Team. The report provides Program descriptions in Sections 1 through 5. Included are sections on Clean Water Act and Endangered Species Act, monitoring station descriptions, a reference to the detailed 2000 Plan of Action prepared for the Technical Management Team, a summary of 2000 runoff conditions, and a summary of spill conditions. The report summarizes Program results in Sections 6 and 7. They include a review of water quality exceedances and a summary discussion of 2000 fish passage. Detailed reviews of the Program are found in Sections 8 through 12; they include detailed review of the total dissolved gas and water temperature monitoring results, a discussion of data analysis, station analysis, operational considerations, and lessons learned.

The core of the report describing the 2000 results are in Sections 6 and 7. Operation of the Corps lower four Snake River dams and the Corps lower Columbia River dams for Clean Water Act compliance was good.

Water year 2000 was 96 per cent of average, therefore, it was considered near normal.

Total Dissolved Gas (TDG) standard exceedances ranged from 1 day at John Day forebay to 58 days at Camas/Washougal during the 190-day spring/summer monitoring season at Bonneville Dam and the 168-day spring/summer monitoring season at the remainder of the locations. ~~A Poisson Analysis was performed for each fixed monitoring site providing a base measure from which future improvements in operations to reduce the number of exceedances can be measured.~~

Water temperature standard exceedances ranged between 13 and 51 days at the monitoring sites on the Columbia River, between 0 and 63 days at the Snake River sites, and between 1 and 3 days on the Clearwater sites. Dworshak Dam was able to provide waters that cooled the lower Snake River by as much as 2 degrees (F) during some summer periods.

Chronic problem fixed monitoring sites were identified to be the McNary Dam forebay and the Camas, Anatone and Lewiston riverine sites.

According to the 2000 Fish Passage Report prepared by the National Marine Fisheries Service and Fish Passage Center, a total of 21,391 juvenile salmon were examined between April and August 2000. Only 96 fish or 0.4 per cent showed signs of gas bubble trauma in fins, eyes, or lateral lines. Only three fish with signs were observed in the lower Columbia River sites.

2000 DISSOLVED GAS MONITORING
COLUMBIA RIVER BASIN

Table of Contents

Part I – Program Description

1. Clean Water Act and Endangered Species Act

1.1. Purpose

1.1.1. General

There are two purposes for Corps of Engineers monitoring total dissolved gas and water temperature at eight Columbia River Basin dams and preparing this report: to monitor project performance in relation to water quality standards, and to provide water quality data for anadromous fish passage at Columbia/Snake mainstem dams. The monitoring program is considered an integral part of Corps Reservoir Control Center water management activities.

Total Dissolved Gas (TDG) is the primary water quality parameter monitored. High saturation level TDG can cause physiological damage to fish. Water temperature is also measured because it affects TDG saturation levels and because it influences the health of fish and other aquatic organisms. Both TDG and water temperature are closely linked to project water management operations (e.g. water released over the spillways, releases through the powerhouses and other facilities, forebay and tailwater water surface elevations).

1.1.2. Corps Goals

The general policies of the Corps of Engineers are summarized in the **Corps Digest of Water Resources Policies and Authorities**, Engineering Pamphlet 1165-2-1, dated February 1996. The Corps policy is to comply with water quality standards to the extent practicable regarding nationwide operation of water resources projects. "Although water quality legislation does not require permits for discharges from reservoirs, downstream water quality standards should be met whenever possible. When releases are found to be incompatible with state standards they should be studied to establish an appropriate course of action for upgrading release quality, for the opportunity to improve water quality in support of ecosystem restoration, or for otherwise meeting their potential to best serve downstream needs. Any physical or operational modification to a project (for purposes other than water quality) shall not degrade water quality in the reservoir or project discharges." (Section 18-3.b, page 18-5)

1.1.3. Biological Opinions for 1995 and 1998

The Corps Dissolved Gas Monitoring Program before 1984 was to voluntarily monitor for water quality standard exceedance. In 1984, the program was enhanced to serve the dual purposes stated in **1.1.11 General**. Since the listing of some Snake River salmonids under the Endangered Species Act in 1991, voluntary spill for juvenile fish passage has been examined and modified over the last ten years. According to the 1992 Biological Opinion, voluntary spill for juvenile fish for 12 hours at night was conducted at Lower Monumental, Ice Harbor, John Day, The Dalles and Bonneville dam in an attempt to achieve 70% fish passage efficiency (FPE) for spring outmigrants and 50% FPE for summer outmigrants. FPE is an estimated percentage of fish that pass the dam either over the spillway or through a bypass facility. In the NMFS 1995 BiOp, the timing, location and volume of voluntary spill was modified. 24-hour spill was initiated at Ice Harbor, The Dalles, and Bonneville dams; spill at collector projects during the spring migration was initiated; FPE was increased to 80% for all migrants. NMFS concluded that the benefits to project survival associated with fish passage spill up to 120% TDG was an acceptable risk.

The Corps addressed TDG and water temperature during the ESA consultation in 1994. In a letter from the Corps to National

Marine Fisheries Service, dated November 9, 1994, the Corps stated that "Spill for fish passage at Corps projects will be provided in 1995 according to the Fish Passage Plan (FPP) criteria, including any modifications agreed upon in consultation under the Endangered Species Act (ESA)…Also, any necessary waivers of water quality standards must be obtained beforehand from appropriate state or Federal authorities..."

The 1998 Supplemental BiOp replaced the FPE goals with spill levels up to 120% TDG. The NMFS 1998 BiOp also asked the Corps to test increasing voluntary spill at John Day Dam from 12 hours to 24 hours. Therefore, in order to meet the ESA requirements of avoiding jeopardy to listed salmonids, the Corps has been asked to provide voluntary fish passage spill which exceeds state water quality standards of 110% TDG. Relevant sections of the 1995 and 1998 BiOps regarding operations that impact TDG levels and water temperature include:

TDG

RPA #2 in the 1995 BiOp identified additional voluntary spill at the lower Snake river projects to achieve 80 percent fish passage efficiency (FPE) and survival of migrating juvenile salmonids (1995 BiOp, pages 104 - 110). At certain projects, voluntary spill up to 110 per cent TDG would not achieve 80 per cent FPE. Therefore, recommending spill levels above the state water quality standard of 110 per cent. NMFS considered the risk of the elevated levels of TDG on migrating salmon and decided the risk was acceptable. In the 1998 Supplemental Biological Assessment, the action agencies proposed that voluntary spill be minimized at lower Snake River projects due to concerns of high TDG and to maximize fish transportation by barges. During consultation with NMFS this proposal was amended and the 1998 Supplemental BiOp increased the voluntary spill levels partially based on observations made after 1995. "NMFS also believes that moving past the per-project FPE goals (stated in the 1995 RPA) to further increase juvenile survival would not violate the intent of the requests to the state water quality agencies for dissolved gas waivers." (98BiOp, page c-4) NMFS recommended maximum spill up to the higher total dissolved gas levels rather than curtailing spill when 80% FPE were achieved, which the Corps agreed to implement. (98ROCASOD)

Water Temperature

Water management operations to reduce water temperature in the lower Snake River for the benefit of adult Snake River fall Chinook salmon were considered. (95 BiOpIV.A.1.g, pages 44 - 45) The BiOp concluded that although the priority for cool water releases from Dworshak Dam were for migrating juvenile fall chinook in July and August, releases to reduce water temperatures in September could be considered on an annual basis through the NMFS Regional Forum's Technical Management Team. Incidental Take Statement # 17 of the 1995 BiOp specifically recognizes the potential releases from Dworshak Dam for water temperature control.

Incidental Take Statement # 5 of the 1995 BiOp also recognizes special operating criteria to mitigate adverse warm water conditions that periodically occur at McNary Dam in the summer.

1.1.4. Operating Guidelines

The Water Quality Team of the Reservoir Control Center is responsible for monitoring the TDG and water temperature conditions in the forebays and the tailwaters of each of the eight lower Columbia River/lower Snake River dams, and selected river sites. The operational water management guidelines are to change spill levels and, subsequently, spill patterns at the dams (daily if necessary) so that the forebays are as close to, but do not exceed, 115 per cent TDG and the tailwater are as close to, but do not exceed, 120 per cent TDG.

2. Monitoring Stations

Total Dissolved Gas (TDG) and temperature are monitored throughout the Columbia River basin using fixed monitoring stations (FMSs). There are a total of 41 FMSs in the United States portion of the Columbia River basin. The US Bureau of Reclamation, Chelan and Grant County Public Utility District (PUD) maintain four stations each. Two stations are maintained by Douglas County PUD. The remaining stations are maintained by the US Army Corps of Engineers. It should be noted that the Corps dams on the Pend Oreille River (Albeni Falls Dam) and on the Kootenai River (Libby Dam) were not part of the fixed monitoring station program. Table 1.1 contains points of contact for each FMS. Appendix A contains a map of the fixed monitoring stations and a brief description of each of the Corps FMSs.

The Northwestern Division is not responsible for the monitoring programs of the non-Corps stations. The Corps makes non-Corps data available on the Technical Management Team (TMT) website in cooperation with inter-agency watershed management goals.

Table 1.1 List of TDG Monitoring System Contact Persons

Project	*Name*	*Position*	*Phone #*	*E-Mail/ Fax*
Kootenay and Pend d'Oreille projects/Keenleyside	Andrea Ryan Julia Beatty	Environmental Specialist Biologist	(604) 664-4001 (250) 354-6750	Andrea.ryan@gc.ca jbeatty@nelson.env.gov.bc.ca
International Boundary Hungry Horse, Grand Coulee	Sharon Churchill Dave Zimmer Jim Doty	Water Quality Specialist Biologist/Coordinator Engineer/Transmission	(509) 754-0254 (208) 378-5088 (208)378-5272	(509) 754-0239 schurchill@pn.usbr.gov
Chief Joseph, Libby	Marian Valentine David VanRijn Ray Strode	Hydraulic Engineer/ Coordinator Biologist Meteorological Tech	(206) 764-6927 (206) 764-6926 (206) 764-3529	(206)764-6678 marian.valentine@usace.army.mil (206)764-6678 david.p.vanrijn@usace.army.mil (206)764-6678 i.ray.strode@usace.army.mil
Wells (Douglas County PUD)	Rick Klinge Dan Gerber Scott Wilsey	Biologist/Coordinator Technician Program Analyst	(509) 884-2244 (509) 884-7191 x352 (509) 884-7191 x219	(509) 884-0553 rklinge@dcpud.org
Rocky Reach, Rock Island (Chelan County PUD)	Robert MacDonald	Biologist/Coordinator	(509) 663-8121	(509) 664-2898 robertmc@chelanpud.org
Wanapum, Priest Rapids (Grant County PUD)	Tom Dresser	Biologist/Coordinator	(509) 754-5088 x2312	
Dworshak, Lower Granite Little Goose, Lower Monumental Ice Harbor, McNary	Dave Reese Gary Slack Tom Miller Russ Heaton	Hydraulic Engineer/ Coordinator Technician Limnologist Technician	(509) 527-7283 (509)527-7636 (509) 527-7279 (509) 527-7282	David.l.reese@nww01.usace.army.mil Gary.m.slack@nww01.usace.army.mil Thomas.d.miller@nww01.usace.army.mil Russ.d.heaton@nww01.usace.army.mil
John Day, The Dalles, Warrendale, Skamania, Camas/Washougal	Jim Britton Joe Rinella Dwight Tanner	Biologist/Coordinator USGS USGS	(503)808-4888 (503) 251-3278 (503) 251 3289	James.l.britton@nwp01.usace.army.mil Jrinella@usgs.gov
US Army Corps of Engineers Coordination	Richard Cassidy Ruth Abney	Environmental Engineer Hydrologic Technician	(503) 808-3938 (503) 808-3939	Richard.A.Cassidy@usace.army.mil Ruth.A.Abney@usace.army.mil
Willamette Valley Projects	Bob Magne	Biologist	(541) 937-2131	Robert.a.magne@usace.army.mil
Common Sensing, Inc	Brian D'Aoust	Company President	(208) 266-1541	(208) 266-1428 Comsen@dmi.net
HydroLab, Inc	Jim Flynn	Electrician	(800) 949-3766 x242	Jimflynn@hydrolab.com

3. Monitoring Plan of Action

The Corps prepares a dissolved gas Plan of Action each year. It is a supporting document of the National Marine Fisheries Service Regional Forum Technical Management Team (TMT). The 1995 Biological Opinion called for the establishment of a Technical Management Team to make recommendations to operating agencies to optimize passage conditions at dams for juvenile and adult anadromous salmonids for the Columbia/Snake hydro system. The 1995 Biological Opinion, and subsequent BiOps, called for the establishment of a Technical Management Team to optimize passage conditions at dams for juvenile and adult anadromous salmonids. A website description of the TMT can be found at:

http://www.nwd-wc.usace.army.mil/TMT/

The 2000 Plan of Action can be found listed under the Supporting Documents category of the 2000 TMT web page. The web address is:

http://www.nwd-wc.usace.army.mil/TMT/2000/documents/tdg/

It is also attached in Appendix B. The Plan summarizes the role and responsibilities of the Corps as they relate to dissolved gas monitoring, and what to measure, how, where, and when to take the measurements and how to analyze and interpret the resulting data. It also provides for periodic review and alteration or redirection of efforts when monitoring results and/or new information from other sources justifies a change. The Plan identifies channels of communications with other cooperating agencies and interested parties.

Part II – Program Operating Conditions

4. Water Year Runoff Conditions

Precipitation during water year 2000 in the upper Columbia River Basin was 100 per cent of normal (1961 - 1990) above Grand Coulee Dam, 85 per cent of normal in the Snake River upstream of Ice Harbor Dam, and 96 per cent of normal in the Columbia River above The Dalles, Oregon (Western Region Climate Center). The accumulated runoff for water year 2000 was 115,200 cubic feet per second or 102 per cent of average (1961 - 1990) above The Dalles. On the Snake River above Weiser, Idaho the accumulated runoff was 13,610 cubic feet per second or 84 per cent of average. This information was obtained from the US Geological Survey and Natural Resources Conservation Service.

5. Release Conditions

5.1 Spill

5.1.1. Special Spill Operations

There were three special spill operations in 2000, a Bonneville/Spring Creek Hatchery release operation, a Bonneville/John Day daytime spill amount test, and a John Day deflector spill test.

Only the Bonneville/John Day daytime spill amount test caused chronic TDG standard exceedances. The daytime spill amounts at John Day and Bonneville were varied from normal operating amounts from April 20 to August 29, 2000. At Bonneville, the daytime spill amount was varied between the normal daytime spill level of 75 kcfs and a test condition of spilling to the 120/115% TDG gas cap. The primary purpose of this test was to determine the effects of the higher spill amounts on adult fallback to see if the spill level could be increased without harmful effects on adult passage. At John Day, the daytime spill amount was varied between the normal 0% daytime spill and 30% spill. The primary purpose of this test was to see the effect of the increased spill on juvenile fish passage. At both projects, adult and juvenile fish passage was monitored to determine observed effects. These tests were designed using a randomized block design. Each block was six days long and consisted of 2 three-day test periods. The test consisted of spilling either 0% or 30% during daytime hours at John Day and spilling during the daytime at Bonneville to either the 75 kcfs adult fallback cap or the 120/115%TDG gas cap.

These two tests were linked. On the days that John Day was spilling 30% of flow during daytime Bonneville was spilling to the 75 kcfs adult fallback limit. Conversely, on the days that John Day was spilling 0% of the flow during the day Bonneville was spilling during the day to the 120% TDG cap.

The testing at these two projects caused parcels or blocks of water with differing levels of TDG to occur. The leading and trailing edges of the parcels, characterized by different gas levels, and the travel time affected by tidal influences made compliance with the 115 % cap at Camas a chronic problem.

This long-term test resulted in 6-12 days of exceedence of the 120% cap at Warrendale, Skamania and the tailrace of John Day. The results at Camas were 58 days over 115%, mainly because of large volume of daytime spill patterns producing higher gas per volume spill. It has been observed that gas does not dissipate at a high rate in the river reach between the Bonneville tailrace and Camas.

5.1.2. Voluntary and Involuntary

Within the Columbia River Basin there is an interest in correlating TDG standard exceedances and times of involuntary spill at the projects. Appendix C: Section 1 contains a summary of voluntary and involuntary spill at the eight mainstem Snake and Columbia River projects. The information was reproduced from the Bonneville Power Administration (BPA) website.

In compiling this information it should be noted that the definitions of voluntary and involuntary spill are not straightforward or consistent. An example of the inconsistency is that some agencies define all water spilled to the spill caps as voluntary while others indicate that if there was a lack of market load during the spill that was occurring then the amount defined as voluntary would be reduced by the amount ascribed to lack of market load which would then be considered involuntary spill.

According to the definitions provided by BPA in preparing this information, involuntary spill occurred throughout the spill season at Bonneville, The Dalles and John Day Dams. The greatest percentage of involuntary spill occurred in the spring, as would be expected, due to the spring runoff. All spill at McNary dam was defined as involuntary. A portion of the spill was defined as involuntary at Ice Harbor, Lower Monumental, Little Goose and Lower Granite.

5.2 Temperature

5.2.1 Dworshak Releases

During the mid to late summer, water releases from Dworshak Dam were adjusted and used to cool the lower Snake River. Appendix C: Section 2 contains a graph showing water temperatures at Anatone, WA, and at the Lower Granite Dam forebay. The Anatone station represents mainstem Snake River temperature before influences from Dworshak Dam releases. The Lower Granite Dam forebay temperatures represent cooler conditions resulting from Dworshak dominated cool water from the Clearwater River. July and August 2000 water temperatures at the Lower Granite Dam forebay appears to often be up to 2°F cooler because of the contribution from Dworshak Dam.

Part III – Program Results

6. Water Quality Compliance Review

6.1. Total Dissolved Gas

The National Marine Fisheries Service (NMFS) 1995 and 1998 Biological Opinion Spill program was implemented to provide passage conditions for listed anadromous salmonids. The BiOp spill program results in exceedances of the state water quality standard for TDG. During the spill season the TDG level in the project forebays and tailwaters was monitored. Adjustments were made to the upstream project spill levels to maintain the average of the 12 highest values in 24 hours in project forebays at less than 115% TDG and the average of the 12 highest values in 24 hours in project tailwaters at less than 120%. The releases from Dworshak were monitored to maintain instantaneous gas levels at less than 110%, the Idaho state standard for TDG.

Appendix D: Section 1 contains a listing of the maximum and minimum TDG values measured at each FMS for each month of the spill season as well as the number of hours and days the TDG standards were exceeded each month.

Most exceedance occurrences were in April and May, during times of involuntary spill, with the exception of the Camas/Washougal gage. The Camas/Washougal TDG levels were difficult to maintain below the state standards due to water travel times from Bonneville Dam and the spill test occurring at Bonneville which oscillated between spilling to the gas cap or was limited to 75 kcfs in three day random blocks.

6.2. Temperature

Generally, the state water quality standard for Washington and Oregon for temperature is 68°F with more specific criteria about how much the temperature can increase due to human actions when the river temperature exceeds 68°F.

The NMFS 1995 and 1998 BiOps call for cold-water releases from Dworshak reservoir. These releases are to reduce and/or maintain a cooler water temperature in the Snake River in the July and August timeframe when ambient conditions would typically cause the temperature to rise above 68°F.

Appendix D: Section 2 contains a summary of the first and last hour the temperature at each station was equal to or greater than 68°F during the spill season, and the first and last day the 24-hour average temperature was equal to or greater than 68°F during the spill season. The table also contains the number of days where at least one hourly reading was equal to or greater than 68°F and the number of days the 24-hour average was equal to or greater than 68°F.

The 24-hour average temperature exceeded 68°F for between 13 and 51 days at the stations on the Columbia River. The 24-hour average temperature exceeded 68°F for between 0 and 63 days on the Snake River. The 24-hour average temperature exceeded 68°F between 1 and 3 days on the Clearwater River.

6.3. Chronic Exceedance Problems

There were four locations that were difficult to avoid exceedances, leading to chronic exceedance problems for 2000, described below: one was a project location (McNary forebay) and three were river locations (Camas on the Columbia River, Anatone on the Snake River, and Lewiston on the North Fork Clearwater River).

6.3.1. McNary

The McNary forebay is at the confluence of the Snake and Columbia Rivers and receives waters that have not been fully mixed. Consequently, the water coming from the mainstem Columbia on the Washington side of the river often contains different TDG levels and water temperatures from the waters entering from the Snake River on the Oregon side. The only control that the Corps has in changing forebay conditions at McNary are by operating Ice Harbor Dam releases on the Snake River. For example, it was difficult making decisions on how much to reduce spill at Ice Harbor Dam on the lower Snake River when TDG levels coming down the main stem Columbia River were high or above the 115 percent forebay limit. Sometimes, the TDG level in the Ice Harbor tailwater needed to be significantly reduced below the 120 per cent goal to help reduce the McNary forebay levels which were above 115 per cent. This resulted in spill levels at Ice Harbor that were less than the 120 percent called for in the Biological Opinion.

6.3.2. Camas

The Camas fixed monitoring site represents a theoretical forebay site in the lowest reach of the Columbia River, a site that is influenced by tidal interaction. Tidal interaction probably influenced the water travel time of parcels of water spilled over Bonneville Dam. Typically the travel time was 12 to 15 hours. This site was the most difficult fixed monitoring site to operate near to, without exceeding 115 per cent total dissolved gas levels. See Appendix E for a graph depicting exceedances.

This site was also significantly affected by environmental conditions such as changes in barometric pressures and changes in daily solar radiation and resulting water temperatures. Other important factors influencing problematic total dissolved gas fluctuations were the randomly determined three-day daytime spill treatments performed for fisheries experimental evaluations. The Portland District will be evaluating the representativeness of the Camas FMS in 2001.

6.3.3. Anatone

The Anatone fixed monitoring site is a riverine site representing lower Snake River conditions that enter the Lower Granite Dam pool and forebay. The site was subject to low water conditions late in the summer monitoring season. Consequently, the compensation depth at which gas bubbles could form on the membrane of the monitoring probe was exceeded. There was some natural correction to this situation because the flowing water of the river tended to sweep forming gas bubbles off the membrane so that the measurement still represented the gas value of one atmosphere near the surface. See Appendix E for the TDG levels measured at this site.

6.3.4. Lewiston

The Lewiston fixed monitoring site was a Clearwater River monitoring site that also experienced the same type of compensation depth problem as at Anatone due to the level of the river. The probe at this site was actually above the surface of the water late in the summer. See Appendix E for the TDG levels measured at this site.

6.3.5. Compensation depth

There were 3 tailwater fixed monitoring sites that could be characterized as being shallow for portions of the spring/summer monitoring season. These were Anatone, Lewiston and Warrendale. Compensation depth problems began in mid-July at the Lewiston gage and in late August 2000, at the Warrendale gage and remained an issue through September 15, 2000. Gage depth will be measured at each site in 2001. This information, as well as the calculated compensation depth, will be posted with the hourly data on the TMT website.

7. Fish Passage Summary

An annual report on water year 2000 fish passage for the Columbia River prepared by NMFS and the Fish Passage Center can be found at http://www.fpc.org/fpc_docs.htm. According to the report, the monitoring of juvenile salmonids was conducted at Bonneville and McNary dams in the lower Columbia River, and at Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams on the Lower Snake river. A total of 21,391 juvenile salmon were examined for gas bubble trauma between April and August 2000. A total of 96 or 0.4 per cent showed some signs of gas bubble trauma in fins, eyes, or lateral lines. Only 3 fish with signs were observed in the lower Columbia River sites throughout the spring and summer spill season. These were the lowest observed since monitoring began in 1995.

8. TDG and Water Temperature Monitoring Results

8.1. TDG – Average of the high 12 values in 24 hours

Consistency with state water quality standards for TDG in Oregon and Washington is based on the calculation of the average of the 12 highest values in a 24-hour period. Appendix E contains charts of the calculated TDG values for each monitoring station during the spill season along with a representation of the applicable standard (forebay at 115% or tailwater at 120%).

There were 95 exceedances among all locations on the Snake River with the most problematic locations being the Lower Monumental and Ice Harbor forebays. There were also exceedances at the Columbia River mainstem monitoring stations with the Camas/Washougal gage exhibiting 58 days over state standards.

8.2. TDG – Hourly flow, spill and TDG

Supersaturated water is a result of spill operations at the projects. The charts contained in Appendix F represent the hourly flow, spill and TDG data for each monitoring station. These charts show the relationship between elevated TDG levels and spill.

The Lower Granite tailwater graph is a good representation of the relationship between spill and TDG. During June, operations at the project were varying between 0 spill and the 120% spill cap. The TDG fluctuations directly track the changes in spill.

8.3. Temperature – Hourly data

Appendix G contains graphical hourly temperature data. Temperature exceeded 68°F on the Snake River at Anatone, Lower Granite forebay, Little Goose forebay and tailwater, Lower Monumental forebay and tailwater, Ice Harbor forebay and tailwater for most of July and August.

Temperature exceeded 68°F on the Columbia River at McNary forebays (Oregon and Washington) and tailwater, John Day forebay and tailwater, The Dalles forebay and tailwater, Bonneville forebay, Skamania, Warrendale and Camas/Washougal for most of July and August.

9. Data Analysis

9.1. Data Collection

9.1.1. Environmental Factors

The Total Dissolved Gas (TDG) concentrations measured within the Columbia and Lower Snake River reaches are a function of solubility, water temperature, pressure, and gas composition, and are influenced by daily project operations of the hydropower system.

The TDG pressure in water is composed of the sum of the partial pressures of atmospheric gases dissolved in the water. The primary gases making up TDG pressure in water are nitrogen, oxygen, carbon dioxide and argon and the atmospheric composition of these gases are 78.084, 20.946, 0.934 and 0.032 per cent respectively. In most freshwater systems the partial pressure of carbon dioxide and argon are considered negligible as they contribute less than 1% to the total TDG pressure composition.

Each gas exerts a pressure, its partial pressure, in a volume of a mixture and the solubility of TDG is directly related to these partial pressures exerted in the water column. Each gas exerts the same pressure that it would exert if it alone occupied a volume of water at a given temperature. Dalton's Law and Henry's Law help describe the behavior of gases. According to Dalton's Law, the total pressure exerted by the mixture of gases is equal to the sum of the partial pressures of the constituent gases. Henry’s Law is an equation of state that relates the solubility (mass/volume typically mg/l) of a given gas to the partial pressure (mm Hg) at equilibrium. The constant of proportionality between the partial pressure and solubility is called Henry’s constant or the Bunsen coefficient. The constant of proportionality is a function of barometric pressure, temperature, and salinity. The mass of dissolved gases in water can be determined from estimates of the TDG pressure, water temperature, and barometric pressure (assuming atmospheric composition of gases in solution and the air is saturated with water vapor).

Solubility is the degree to which an individual gas dissolves into a liquid and varies directly with absolute pressure at sample depth. The total pressure is a measurement that combines the effects of barometric pressure and the hydrostatic pressure. When the barometric pressure changes, there is usually a resultant change in the total dissolved gas pressure, and consequently, in solubility. A rise in barometric pressure will result in a reduction in the percent saturation although the total mass and pressure of dissolved gas remains unchanged. For example, average barometric pressures are lower at higher elevations. Even if total mass and pressure of the dissolved gases remained unchanged, a100-ft elevation drop would translate into an increase in barometric pressure of about 2.7 mm Hg resulting in a slightly higher percent saturation at the higher elevation.

In late March 2000, there were barometric pressure changes in the Snake River Basin that affected the total dissolved gas readings at the monitor. It was most noticeable in the Lower Granite Dam forebay March 20 through 22, 2000. During March 20 and 21, the barometric pressure was between 752 and 746 mm Hg. On March 22, the barometric pressure dropped to the 739 - 740 mm Hg range. Because of the decreased solubility of dissolved gases with the change in barometric pressure, the total gas saturation level increased to supersaturated conditions even though little or no spill was occurring in the Snake River system. The occurrence is less noticeable but still identifiable at Little Goose and Lower Monumental dams and least noticeable at Ice Harbor Dam.

Under most conditions, water temperature increases closer to the surface of the water column. Temperature gradients can cause pressure increases of several mm of Hg. Warming of water without corresponding equilibrium with the atmosphere can cause significant supersaturation. A 1-degree Celsius change in water temperature is equivalent to about a 12 mm Hg (2% saturation) change in the total dissolved gas pressure. As the temperature increases, solubility decreases. For example, the solubility of nitrogen at zero degrees Celsius (or 32 degrees Fahrenheit) is 55 per cent greater than at 20 degrees (Celsius, or 68 degrees Fahrenheit). The physical manifestation of this decreased solubility is readily forming gas bubbles that rapidly vent out of the water column. Barring any other environmental changes, this increase in temperature translates into higher TDG pressure readings by the monitor.

Daily water temperature variations caused by solar radiation during clear days, following extended periods of cloudy conditions at a monitoring station measuring at 15-foot depth, cause increases in TDG pressure in late afternoon. This is because the gases within the surface waters have not had sufficient time to reach equilibrium with the atmosphere. Typically, the total dissolved gas pressure in the mass of water for a specific river reach does not change, however, it takes several hours for the monitor to equilibrate from the barometric changes and the water temperature changes. Since the solar radiation lasts for only a portion of the day, the monitor can be recording unstable conditions that appear to be supersaturated for several hours. The monitors actually show only a segment of the water column and may appear exaggerated. See the daily total dissolved gas cap changes at the Corps dams made on the lower Snake River during the first two weeks of June 2000 for an example of this phenomena. The daily decision rationale for adjusting spill levels including consideration of fluctuating daily air temperatures are shown in Appendix H.

Other environmental factors that affect total dissolved gas pressure include photosynthesis, respiration, wind mixing effects, and salinity levels. Photosynthesis occurs as plankton metabolizes, producing oxygen whilst respiration by plankton consumes oxygen. A 1-mg/l change in the dissolved oxygen concentration level can result in a 14 to 17 mm Hg total dissolved gas change between 10 and 20 degrees Celsius (50 to 68 degrees Fahrenheit), or a 2% change in the gas saturation level. Salinity reduces TDG pressure and increases the percent of partial pressure. Wind mixing occurs extensively in the John Day pool, causing fluctuations in gas pressures.

9.2. Operational Factors

The Dissolved Gas Abatement Team conducted a five-year joint study to better understand the TDG production systems occurring at the eight Lower Columbia River projects. The study has provided a greater understanding of the processes and much of this work will be available in the Phase II Dissolved Gas Abatement Technical Report. In general, TDG exchange processes can be divided into two broad categories: near field and in-pool.

Though these processes are complex, some patterns do emerge. Using the ERDC-generated TDG production equations, the Reservoir Control Center formulates an annual spill priority list to allot spill to projects in a manner that best manages TDG levels to the state water quality standards.

RCC assigns voluntary spill levels to each project during the spill season, however this spill level may vary in-season because of environmental, operational or hydrodynamic factors. For example, temperature may rise, resulting in higher TDG for the same spill level. Unit outages may occur, forcing more spill but at a lower total percent powerhouse discharge and the voluntary spill level may need to be lowered accordingly.

9.3. Hydrodynamics/Spill

Each Corps of Engineers hydropower project produces TDG levels unique to that project. Most of the TDG is generated through spillway related activities. In general, spillway water falls over or moves through the dam spillway and the increased air-water interface causes atmospheric gases to go into solution. The water is forced deep into the plunge pools of the dams and the water can pressurize several atmospheres of hydrostatic pressure from the weight of the water, causing gas supersaturation. For example, at a depth of 15-feet the absolute saturation value is 45 % more that the saturated value at the surface (e.g. 155% at the surface is equivalent to 110% at 15 feet).

The hydrodynamics associated with the interactions of the spillway and powerhouse is unique to each project and is, as the word implies, dynamic. The hydrodynamic processes between powerhouse and spillway flows may vary throughout a given day through changes including total river flow, percent powerhouse to spillway discharge and incoming TDG levels. The processes at some projects are more complicated than others. Bonneville is particularly difficult to manage to state water quality standards for several reasons such as variable flow from two powerhouses and the unique bathymetric features of the dam spillway stilling basin.

9.4. Standards of Measurement

Various approaches may be taken in quantifying dissolved gases using the standard parameter of TDG expressed either as a percent of saturation (in relation to local atmospheric pressure) or as delta pressure (total gas pressure as mm Hg in excess of the local atmospheric pressure, ΔP). The Standard Methods for the Examination of Water and Wastewater, 20th Edition, (authored by the American Public Health Association, American Water Works Association and the Water Environment Federation) discourages reporting total dissolved gases in terms of percent saturation, concentration or volume units and prefers describing TDG in terms of pressures. However, within the Columbia River Basin hydropower management community, it has become conventional to express the total dissolved gas concentrations as per cent (%) of saturation as measured at the surface, or zero depth. The test criteria for acceptable aquatic habitat as applied to fresh waters for protection of biological communities is generally the universally accepted federal Clean Water Act standard of 110 percent saturation as compared to barometric pressure for the reach.

As mentioned, dissolved gas pressures are generally measured and reported as ΔP and TDG (percent) with respect to local barometric pressure (Colt, 1984). The actual or effective ΔP or TDG (percent) experienced by aquatic organism at depth as determined by the equilibrium solubility of a bubble at depth is the uncompensated pressure (Colt, 1984, 1983, and SM 1992). These values are calculated according to equations presented in "Computations of Dissolved Gas Concentration in Water as Functions of Temperature, Salinity, and Pressure" (Colt, 1984) and incorporate the physical effects of hydrostatic head on the gas solubility.

$$\Delta P_{uncomp} = TDGP - (BP + P_{Hydrostatic});$$
$$TDG_{uncomp} = [(BP+\Delta P)/(BP+ P_{Hydrostatic})]\,100;$$

The hydrostatic head is:

$$P_{Hydrostatic} = \rho gZ,$$

where ρ = the density of water in kg/m
g = acceleration of gravity (9.80655 m/s^2)
Z = depth in meters.

Gas bubbles form only when the TDG pressure is greater than the sum of compensating pressures (SM, 1992). These compensating pressures include the water (or hydrostatic) as well as barometric pressure. For organisms, tissue or blood pressure may add to the compensating pressures. Gas bubble disease or trauma can only result if internal ΔP_{uncomp} is greater than 0 or the TDG_{uncomp} is greater than 100 percent (see Section 2). The depth where $\Delta P_{uncomp} = 0$ is referred to as the hydrostatic compensation depth.

Below this compensation depth it is not possible for the dissolved gases to form bubbles or to come out of solution. Above this depth bubbles can form either internal to biological organisms or in the water column. Bubble formation on the silicone rubber tubing used by membrane diffusion instruments can seriously reduce the measurement accuracy (SM, 1992). The formation of bubbles on the membrane, which can be expected to occur at depths shallower than compensation depth, can induce a downward bias into the measure in relation to the hydrostatic pressure for that depth. If the probe is situated at 15 feet (or about a half a standard atmosphere), and TDG is managed to 120% or less, then no bubbles would be expected to form on the monitor membrane and hence no bias in the monitor measures. Positioning the monitor to at least 15 feet offers the additional advantage of being deep enough not to be uncovered during pool fluctuations and is generally representative of the entire water column. Sites that often do not meet the minimum depth of 15 feet include Warrendale and Skamania on the Lower Columbia River, Lewiston and Peck on the Clearwater River and Anatone on the Upper Snake River.

There are several basic methods to measure total dissolved gases including a manometric, volumetric, mass spectrometric, gas chromatographic, chemical titrimetric or the most common method, the direct pressure transducer method. The Corps uses the direct pressure transducer method for the fixed monitoring stations as described in this report. This analytical technique is efficient and is considered more precise than other methods of measurement.

9.5. Instrument Errors/Data Bias:

Measurement inaccuracies in data collection arise from many sources. They can originate from the position, location or operation of the instrument, or from the instrument itself. An error in any one measurement is considered a fixed, given value. The possible value of that error is described as an uncertainty. It is a statistical variable that can be arrived at through a process of uncertainty analysis. Typically, the measurement reported is considered to be the mean estimate. The uncertainty describes the variation of the measurement about the mean. The uncertainty of any measurement is defined as a combination of precision (random) uncertainty and bias (fixed or systematic) uncertainty. (Abernathy, Benedict, and Dowdell 1985). Precision uncertainty can be introduced into any repeated measurement by the variability of the instrument. Bias uncertainty will similarly effect each measurement resulting from a calibration or positioning error. Refer to Appendix I for discussions from each district on the instrument error for their stations.

9.6. Data Completeness

9.6.1. Data Corrections

Corrections to the data received from the FMSs were made throughout the monitoring season. These corrections were not available in the real-time reports for operational decision-making but they are reflected in the historical reports on the TMT webpage.

Corrections, in this context, mean that data values were changed if said changes were provided by the district or district representatives in the form of instrument drift or data shifts. Data was also removed from the database in the following instances:

- The barometric pressure data was reviewed and values <700 or >800 mmHg were removed.
- The TDG pressure data was reviewed and values <700 or >1100 mmHg were removed.
- The TDG pressure data was reviewed and changes between hourly values of >50 mmHG were removed.
- Temperature data was reviewed and temperatures >75°F were removed.

9.6.2. Overview of TDG Data Completeness

STATION	15 Dec 1999- 15 Mar 2000	1 Apr - 15 Sep 2000
Anatone (ANQW)	99.7%	99.6%
Bonneville (BON)	N/A	97%
Camas/Washougal (CWMW)	N/A	99%
Chief Joseph (CHJ)	N/A	99%
Downstream (CHQW)	N/A	99%
Peck (PEKI)	N/A	94%
Dworshak (DWQI)	97%	97%
Ice Harbor (IHR)	95%	99.6%
Tailwater (IDSW)	97%	99%
John Day (JDA)	N/A	99%
Tailwater (JHAW)	N/A	99%
Lewiston (LEWI)	N/A	89%
Little Goose (LGS)	N/A	99.9%
Tailwater (LGSW)	N/A	99%
Lower Granite (LWG)	99.7%	99.9%
Tailwater (LGNW)	95%	99.8%
Lower Monumental (LMN)	N/A	99.7%
Tailwater (LMNW)	N/A	98%
McNary (MCN)		
Oregon Forebay (MCQO)	99.7%	99%
Washington Forebay (MCQW)	99%	99.9%
Tailwater (MCPW)	99.7%	99%
Pasco (PAQW)	N/A	98%
Skamania (SKAW)	N/A	99.3%
The Dalles (TDA)	N/A	98%
Downstream (TDDO)	N/A	99.8%
Warrendale (WRNO)	98%	99%

9.6.3. Overview of Temperature Data Completeness

STATION	15 Dec 1999- 15 Mar 2000	1 Apr- 15 Sep 2000
Anatone (ANQW)	99.7%	99.6%
Bonneville (BON)	N/A	97%
Camas/Washougal(CWMW)	N/A	99.5%
Chief Joseph (CHJ)	N/A	88%
Downstream (CHQW)	N/A	99%
Peck (PEKI)	N/A	94%
Dworshak (DWQI)	97%	97%
Ice Harbor (IHR)	95%	99.8%
Tailwater (IDSW)	97%	98%
John Day (JDA)	N/A	99.9%
Tailwater (JHAW)	N/A	99%
Lewiston (LEWI)	N/A	90%
Little Goose (LGS)	N/A	99.9%
Tailwater (LGSW)	N/A	99%
Lower Granite (LWG)	99.7%	99.9%
Tailwater (LGNW)	95%	99.9%
Lower Monumental (LMN)	N/A	99.8%
Tailwater (LMNW)	N/A	99%
McNary (MCN)		
Oregon Forebay (MCQO)	99.7%	99%
Washington Forebay (MCQW)	99%	99.9%
Tailwater (MCPW)	99.7%	99%
Pasco (PAQW)	N/A	99%
Skamania (SKAW)	N/A	99.6%
The Dalles (TDA)	N/A	99%
Downstream (TDDO)	N/A	99.9%
Warrendale (WRNO)	N/A	99%

9.6.4. Missing Data

There are multiple reasons why data may be missing from the data set. Examples of reasons include transmission problems, site vandalism, a tear in a membrane or, as exhibited at Lewiston, the river level dropping below the level of the FMS. All efforts are made to reduce the occurrence of missing data.

10. Station Site Analysis

10.1. Dworshak

During the 2000 spill season, cold-water releases from Dworshak reservoir were utilized to maintain cooler water temperatures in the Snake River. Temperature information from resistance thermal devices (RTDs), embedded in the face of the dam at the time of construction, along with an understanding of the overshot and undershot modes of operation of the selector gates were used to determine which elevation of water to release to attain the desired temperature.

Appendix C:Section 2 contains a graph of the Anatone and Lower Granite forebay water temperature. The cooler temperatures in the Lower Granite forebay are attributed to cold water releases from Dworshak Dam.

Appendix C:Section 2 contains graphs of the RTD data compared with temperature array data collected ~0.5 miles from the face of the dam. These charts and the in-season performance on attaining requested release temperatures indicate that the RTD array provide data sufficient for this purpose.

Appendic C:Section 2 also contains schematics of the release structures at Dworshak and some of the physical restrictions associated with them.

10.2. Station Representativeness

The information in this section has been reproduced from the Dissolved Gas Abatement Study, Phase II, 60% Draft Technical Report. Refer to chapter 13 of that document for the complete discussion and data.

OVERVIEW:
The Columbia/Snake River Total Dissolved Gas Monitoring System (TDGMS) consists of a network of water quality monitors that collect data in the forebay and tailrace of each Corp's hydro project in the Columbia and Snake River Basin. The TDGMS was established to provide total dissolved gas pressure and water temperature data for use in adjusting reservoir regulation practices to comply with state mandated total dissolved gas water quality standards. These data are now being utilized by scientists in ways that were not originally considered in the establishment and design of the TDGMS. Although the fixed monitor station (FMS) sites sample water in only one location at a given river mile, the data are being used to represent conditions across the full width of the rivers. This allows the calculation of fluxes of water quality constituents. Due to these and other research needs, the representativeness of the data generated by the TDGMS has become an issue worthy of investigation. As part of the DGAS Field Data Collection effort, an array of three to five logging water quality instruments were deployed on a transect at each FMS site. Parameters logged include total dissolved gas, temperature, and dissolved oxygen. Data collected by these logging instruments were compared to that collected by the adjacent FMSs to determine whether each FMS collected data that were representative of the in-river maximum, mean, and/or near TDG (total dissolved gas) levels.

The fixed monitor TDG readings were compared to the maximum in-river reading, the nearest in-river reading, and the flow-weighted in-river average for each point in time. Representativeness was quantified in two ways, acceptable error analysis and regression analysis.

RESULTS:
The results of the above analyses from data collected during the 1996 and 1997 sample periods can be viewed in the above referenced report. Some of the more salient results follow:

- 16 of 21 FMS's report values within 23 mm Hg of maximum in-river conditions, suggesting that only these 16 adequately measure the maximum gas values present in the river. Only 10 of 21 FMS's have R^2 values greater than 0.7 suggesting that most FMS's cannot be used to model maximum in-river TDG values.
- 18 of 22 FMS's report values within 23 mm Hg of the flow-weighted average in-river conditions. 13 of 22 FMS's have R^2 values greater than 0.7 suggesting that those FMS's values can be used to model average in-river TDG values.
- For the near quad comparison within two instrument precisions, only 6 of 21 monitors fall within acceptable error i.e., 15 of 21 monitors have more than 25% of observations that are more than 6 mm Hg different from the TDG values measured immediately adjacent in the river. That is, instrument precision is less for field measurements. Other sources of errors such as sample error must be present. None-the-less, 20 of 21 FMS's report values within 23 mm Hg of the in-river near-value TDG.

- Forebay fixed monitors are generally most representative of in-river condition, presumably because water above projects is more homogenous.
- NWP and NWW districts have similar success rates, though different equipment, maintenance protocol, and reporting systems are used.

CONCLUSIONS:
Based on the monitor comparisons presented, we conclude that MCPW, LGSW, JHAW, and LGNW monitors are performing inadequately to determine maximum in-river total dissolved gas values. JHAW, LGNW, and LMNW are performing inadequately to determine mean in-river total dissolved gas values. Thus, LGNW is satisfying neither of the possible monitor functions discussed and should be targeted for further study and possible replacement. LGSW does not reflect conditions collected in the water immediately adjacent to the monitor, therefore we recommend additional study at this FMS site.

During 2000, the Camas fixed monitoring station had the most significant chronic exceedance problems. As a result, some NMFS regional forum WQT members have requested that it have a high priority for being evaluated for it's "representativeness".

11. Operation Considerations

There were basic guidelines used to make spill management decisions in 2000. The spill management factors centered around the Corps policy not to exceed state water quality standards. Table 11.1 lists the "Spill Requirements and Other Considerations" at each project for the spill season. This table was reproduced from the 2000 Water Management Plan. For the 2000 spring/summer spill season, the National Marine Fisheries Service (NMFS) obtained variances from the states of Washington and Oregon, according to the 1995 and 1998 Biological Opinion, to have the Corps exceed the total dissolved gas standards of 110 percent in the forebays and tailwaters of the Corps projects to assist migrating salmonid smolts. Up to 115 per cent total dissolved gas (TDG) was allowed in the forebays, and up to 120 per cent in the tailwater below projects was allowed. The method used to achieve desired TDG levels was by changing the daily spill caps restricting the amount of water going over the spillways. The Washington variance is in effect until 2003, however, the Oregon variance was established for only 2000. NMFS did not pursue obtaining a variance from the state of Idaho for 2000 so spill out of Dworshak was limited to maintain TDG levels at or below 110%.

There were six operational factors that affected efforts to control TDG spill levels to within appropriate levels consistent with standards and or variances: adjusting operations for environmental factors, correcting operations to compensate for levels of exceedance, changing operations to adjust for time periods of exceedances, the rates of change of corrected operations, multi-project exceedances, and timing of operational changes.

It is the reservoir control goal to spill as close to the 115 per cent and the 120 per cent criteria as possible, without exceeding those limits. The Reservoir Control Center determined consistency with this goal based on the average of the 12 highest daily TDG readings. The daily operating goal was to have no more than 6 hours of daily TDG values over the variance limits, so that the average of the 12 highest daily values stayed below the gas caps. As discussed in 9.1, the DATA COLLECTION section of the report, environmental factors affected the daily TDG readings. When operating close to the spill caps, environmental factors sometimes negatively affected the ability to operate within TDG caps and exceedances occurred. This type of occurrence was prevalent during weekends because TDG levels are monitored less frequently.

The degree of exceedance was also a factor that affected the calculation of the12 highest daily values. If exceedances were over 1 percent of the variance, larger corrections to spill were necessary to return the location within compliance as soon as possible.

Sometimes, these abrupt corrective actions caused fluctuations throughout long river reaches. Consequently, the TDG level would be reduced more quickly but the TDG level would also drop significantly below the 115 per cent or the 120 per cent cap for several hours. This type of regulation would cause pulsating levels of TDG throughout the system.

Another spill management factor was that once exceedance occurred, the exceedances often continued for greater that 12 hours during the next day because a large mass of water had exceeded the criteria and the water travel time to the next measuring point was greater than 12 hours away. This type of occurrence was especially observed during weekends because the TDG levels are evaluated less frequently. Abrupt TDG changes resulted in lower levels quicker, but it also would cause pulsating levels of TDG throughout the system.

Multi-project exceedances occurred when project forebays exceeded 115 per cent while upstream project tailwaters were significantly below the 120 percent level. This type of exceedance occurred at the tail end of large pulses of > 115 % water masses passing through the river system.

The time that operational changes were initiated could greatly affect TDG compliance. The travel time between forebays and tailwaters greatly affected at what time operational changes should be made.

Table 11.1 Summary of Spill Requirements and Other Considerations
(1998 Supplemental BiOp and Memo issued by NMFS April 13, 2000 based on regional coordination)

Project	Flow trigger	Spill Duration	Recommended Min/Max Powerhouse Capacity (1)	Spill Cap for 120% TDG (2) at the start of the spring season	Other Considerations (per 1998 Supplemental BiOp Appendix C) to prevent eddy formation, improve fish passage, etc.
	Kcfs	**Hours**	**Kcfs**	**kcfs**	**% of flow or kcfs**
LWG	85	12 (4)	11.5/123	45	
LGS	85	12 (4)	11.5/123	60	35% max (3), page C-11
LMN	85	24 (7)	11.5/123	40	50% max (3) page C-11
IHR		24	7.5/94	75	
MCN		12 (4)	50/175	120-160	
JDA		12 (5)	50/	180	60% max (for flows up to 250-300) or TDG cap (whichever is less); 25% min (due to eddy)
TDA (6)		24	50/	230 (5)	(6) 40% max 30% min (test).
BON		24	30 min. (BPA); see page C-14. 60 min. (FPP)	120	50 kcfs min. spill (tailrace hydraulics); 75 kcfs max. daylight hours (adult fallback)

1. Max. value is for powerhouse with units operating within 1% peak efficiency
2. Starting value subject to in-season adjustments based on real-time information
3. Levels provided in the 1998 BiOp to prevent eddy formation and maintain good adult passage conditions. May be adjusted in-season by TMT
4. Normally between 1800-0600 hours
5. From April 20th to May 14 1800 – 0600 from May 15 to July 31 1900 to 0600 and from August 1 to August 31 1800-0600 at John Day.
6. The spill percentage at The Dalles was changed to 40% in memo issued by NMFS April 13, 2000 based on regional coordination.
7. The spill time at Lower Monumental was changed from 12 hours to 24 hours in memo issued by NMFS April 13, 2000 based on regional coordination.

Notes:
Bonneville –Will test the fish passage effect of spilling to the gas cap 24 hours a day. There will a randomized block test consisting of a block of 3 days of spilling during the daylight hours to the gas cap followed by a block of limiting daytime spill to the 75 kcfs adult fallback cap, April 20th to August 30th.

John Day - Will test spilling two levels during the daytime period. A randomized block design consisting of periods of 0% spill and 30% spill during daytime has been suggested. The daytime spill amount will be linked to the spill at Bonneville. John Day would spill during the day when Bonneville was spilling to the daytime 75 kcfs cap and not spill when Bonneville was spilling to the gas cap during the day.

12. Lessons Learned

A major operational consideration for regulating to a spill cap is how to forecast the 12 highest daily readings for the next day or the next few days. There were no analytical tools available to assist in decision-making. Six factors for making spill management decisions were identified during 2000, however, they only provide secondary assistance in providing forecasting guidance. They are discussed in 11.0, Operation Considerations. Environmental factors were generally the root cause of exceedances. Secondarily, regulator decisions to adjust for environmental factors were sometimes a cause of continued exceedances. Experience and observation were the best sources of guidance in 2000.

Appendix A
Monitoring Stations

Gas Monitoring Stations
Spill Season Automated Station
Year-Round Automated Station (as recommended by Dissolved Gas Team)
CANADA
U.S.A.
N
SEATTLE
WASHINGTON
IDAHO
OREGON
ASTORIA
PORTLAND
RICHLAND
Boundary CIBW STN 2830 RM 745.0
RM 706.4
Hungry Horse Dam RM 5.2
HGHM STN 3000
LIBM STN 2900
Libby Dam RM 221.9
Chief Joseph Dam RM 545.1
CHQW STN 2513
CHJ STN 2512
GCGW STN 2616
Grand Coulee Dam RM 596.6
RM 638.9
FDRW STN 1310
WEL STN 2407
Wells Dam RM 515.6
WELW STN 2400
RRH STN 2307
Rocky Reach Dam RM 473.7
RRDW STN 2308
RIS STN 2204
Rock Island Dam RM 453.8
RIGW STN 2205
WAN STN 2100
Wanapum Dan RM 415.8
WANW STN 2104
PRD STN 2007
Priest Rapids Dam RM 397.1
PRXW STN 2004
PAQW STN 2002 RM 329.2
IDSW STN 908
Ice Harbor Dam RM 9.7
IHR STN 916
Lower Monumental Dam RM 41.6
LMN STN 1018
LMNW STN 1003
Little Goose Dam RM 70.3
LGS STN 1118
LGSW STN 1114
LGNW STN 1202
Lower Granite Dam RM 107.5
LWG STN 1205
LEWI STN 1277
PEKI STN 1308
Dworshak Dam RM 41.0
DWQI STN 1312
ANQW STN 1280 RM 167.2
Hells Canyon Dam RM 247
Oxbow Dam RM 273
Brownlee Dam RM 285
McNary (WA) MCQW STN 814
MCPW STN 805
McNary Dam RM 292.0
McNary (OR) MCQO STN 820
JHAW STN 711
John Day Dam RM 215.6
JDA STN 3757
TDDO STN 522
TDA STN 3700
The Dalles Dam RM 191.5
Camas/Washougal CWMW (STN 255) RM 122.0
Skamania SKAW STN 401
Bonneville Dam RM 146.1
BON STN 462
Warrendale WRNO STN 403 RM 140.0
Kettle River
Columbia River
Pend Oreille River & Lake
Kootenai River
Flathead River & Lake
Spokane River
Chelan River & Lake
Wenatchee River
Snake River
Clearwater R.
Cowlitz River
Willamette River
2000
Dissolved Gas Monitoring Network
40 20 0 40 80
APPROXIMATE SCALE IN MILES

US Army Corps of Engineers Fixed Monitoring Station

Station Name *ANQW* **Date Est** *1998* **CROHMS ID** *1280* **Maint Resp** *HDR*

Owner *US Army Corps of Engineers, Walla Walla* **Latitude** *46° 05' 50* **Maint Seq** *Bi-weekly*

Longitude *116° 58' 36* **Calib Resp** *HDR*

River Nam *Snake River*

River Mile

Bank *Left Bank*

Description *River*

Drainage Are

Drainage Acreage: *92960*

Quad Map Name *Limekiln Rapids, I*

Co-located with USGS? ☑

USGS ID *13334300*

Parameter	Unit	Type of calibration	Summer Cal Freq	Winter Station	Winter Cal Freq
Barometric Pressure	mmHG		Bi-weekly	☐	
TDG Pressure	mmHG		Bi-weekly	☐	
Water Temperature	Degrees Celcius		Bi-weekly	☑	
Dissolved Oxygen	mg/L		Bi-weekly	☐	

Station Name *BON* **Date Est** *1986* **CROHMS ID** *462*

Owner *US Army Corps of Engineers, Portland Distr*

Maint Resp *US Geological Survey*

Maint Seq *Bi-weekly*

Calib Resp *US Geological Survey*

Latitude *45° 38' 45*

Longitude *121° 56' 20*

River Nam *Columbia River*

River Mile *146*

Bank *Right Bank*

Description *Forebay*

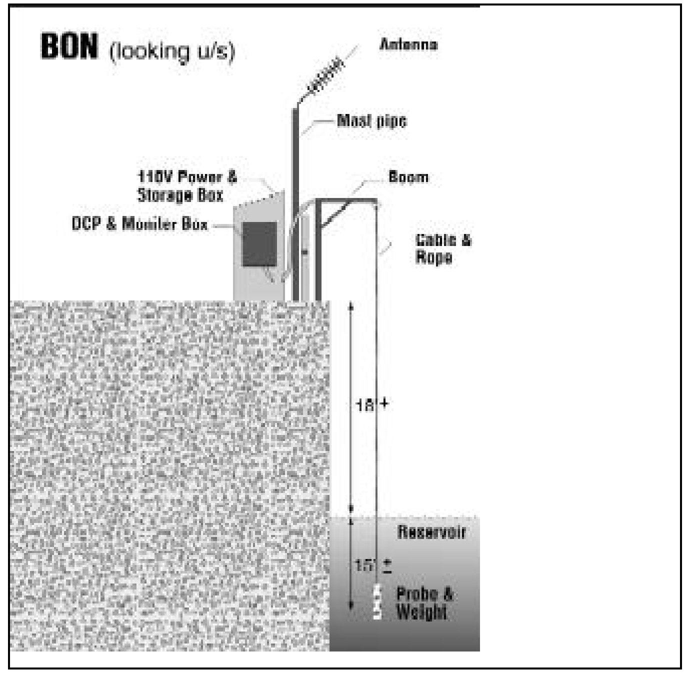
Drainage Are

Drainage Acreage: *239900*

Quad Map Name *Bonneville Dam*

Co-located with USGS? ☐

USGS ID



Parameter	Unit	Type of calibration	Summer Cal Freq	Winter Station	Winter Cal Freq
Gage Depth	Feet		Bi-weekly	☑	Tri-weekly
Barometric Pressure	mmHG		Bi-weekly	☑	Tri-weekly
TDG Pressure	mmHG		Bi-weekly	☑	Tri-weekly
Water Temperature	Degrees Celcius		Bi-weekly	☑	Tri-weekly

Station Name *CWMW* **Date Est** *1993* **CROHMS ID** *255*

Owner *US Army Corps of Engineers, Portland Distr*

Maint Resp *US Geological Survey*

Maint Seq *Bi-weekly*

Calib Resp *US Geological Survey*

Latitude *45° 34' 39*

Longitude *122° 22' 39*

River Nam *Columbia River*

River Mile *122*

Bank *Right Bank*

Description *River*

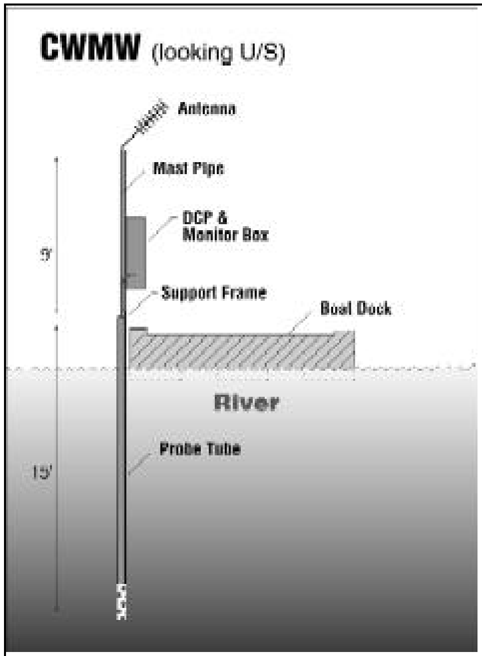
Drainage Are

Drainage Acreage: *241000*

Quad Map Name *Camas*

Co-located with USGS? ☐

USGS ID



Parameter	Unit	Type of calibration	Summer Cal Freq	Winter Station	Winter Cal Freq
Barometric Pressure	mmHG		Bi-weekly	☐	
Water Temperature	Degrees Celcius		Bi-weekly	☐	
Gage Depth	Feet		Bi-weekly	☐	
TDG Pressure	mmHG		Bi-weekly	☐	

Station Name *DWQI* **Date Est** *1994* **CROHMS ID** *1312*

Owner *US Army Corps of Engineers, Walla Walla*

Maint Resp *HDR*

Maint Seq *Bi-weekly*

Calib Resp *HDR*

Latitude *46° 30' 11*

Longitude *116° 19' 18*

River Nam *North Fork, Clearwater River*

River Mile *40*

Bank *Left Bank*

Description *Tailwater*

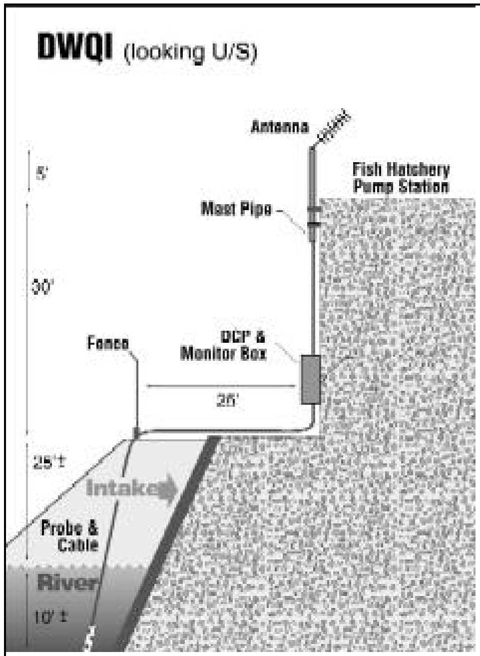
Drainage Are

Drainage Acreage: *2440*

Quad Map Name *Ahsahka, Idaho*

Co-located with USGS? ☐

USGS ID *13341000*



Parameter	*Unit*	*Type of calibration*	*Summer Cal Freq*	*Winter Station*	*Winter Cal Freq*
Dissolved Oxygen	mg/L		Bi-weekly	☑	
Battery Voltage				☑	
Barometric Pressure	mmHG		Bi-weekly	☑	
Water Temperature	Degrees Celcius		Bi-weekly	☑	
TDG Pressure	mmHG		Bi-weekly	☑	
Gage Depth	Feet		Bi-weekly	☑	

Station Name *IDSW* **Date Est** *1990* **CROHMS ID** *908* **Maint Resp** *HDR*

Owner *US Army Corps of Engineers, Walla Walla* **Latitude** *43° 14' 32* **Maint Seq** *Bi-weekly*

Longitude *118° 56' 20* **Calib Resp** *HDR*

River Nam *Snake River*

River Mile *6*

Bank *Right Bank*

Description *Tailwater*

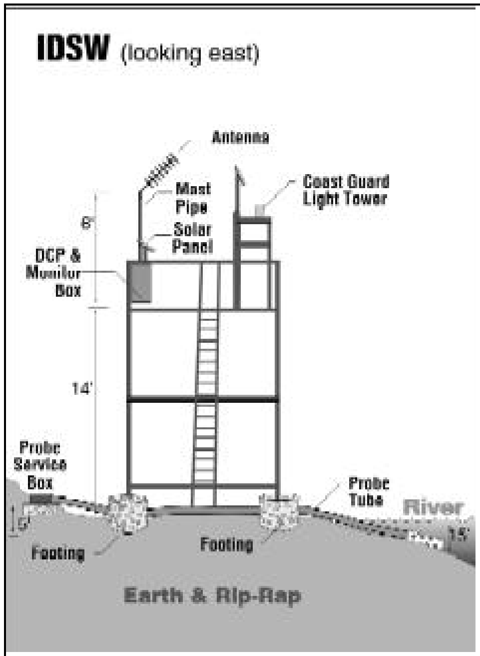
Drainage Are

Drainage Acreage: *109000*

Quad Map Name *Humorist, Washin*

Co-located with USGS? ☐

USGS ID *14019200*



Parameter	*Unit*	*Type of calibration*	*Summer Cal Freq*	*Winter Station*	*Winter Cal Freq*
Barometric Pressure	mmHG		Bi-weekly	☑	
TDG Pressure	mmHG		Bi-weekly	☑	
Water Temperature	Degrees Celcius		Bi-weekly	☑	
Dissolved Oxygen	mg/L		Bi-weekly	☑	

Station Name *IHR* **Date Est** *1984* **CROHMS ID** *916*

Owner *US Army Corps of Engineers, Walla Walla*

Latitude *46° 14' 58*

Longitude *118° 52' 42*

Maint Resp *HDR*

Maint Seq *Bi-weekly*

Calib Resp *HDR*

River Nam *Snake River*

River Mile *10*

Bank *Mid-River*

Description *Forebay*

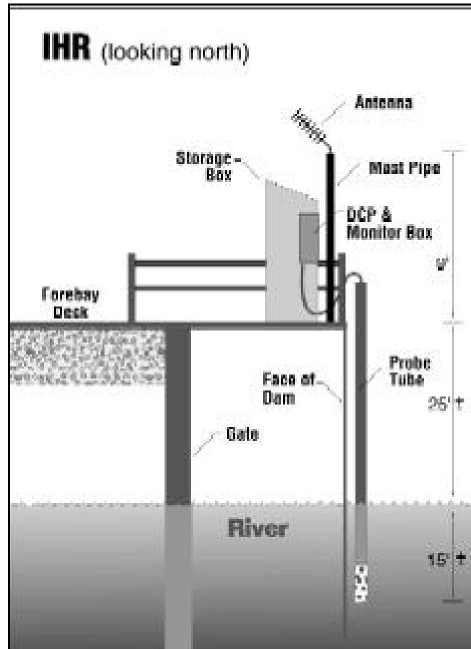
Drainage Are

Drainage Acreage: *109000*

Quad Map Name *Levey SW, Levey,*

Co-located with USGS? ☐

USGS ID *13352950*



Parameter	*Unit*	*Type of calibration*	*Summer Cal Freq*	*Winter Station*	*Winter Cal Freq*
TDG Pressure	mmHG		Bi-weekly	☑	
Dissolved Oxygen	mg/L		Bi-weekly	☑	
Barometric Pressure	mmHG		Bi-weekly	☑	
Water Temperature	Degrees Celcius		Bi-weekly	☑	

Station Name *JDA* **Date Est** *1984* **CROHMS ID** *3757* **Maint Resp** *US Geological Survey*

Owner *US Army Corps of Engineers, Portland Distr* **Latitude** *45° 42' 57* **Maint Seq** *Bi-weekly*

Longitude *120° 41' 30* **Calib Resp** *US Geological Survey*

River Nam *Columbia River*

River Mile *216*

Bank *Mid-River*

Description *Forebay*

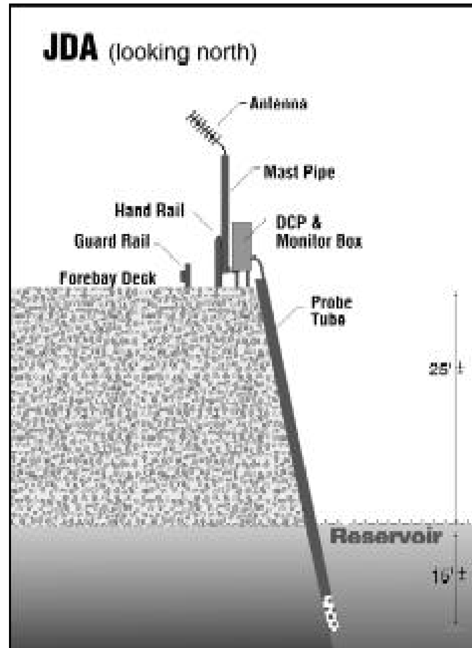
Drainage Are

Drainage Acreage: *226000*

Quad Map Name *Rufus*

Co-located with USGS? ☐

USGS ID



Parameter	Unit	Type of calibration	Summer Cal Freq	Winter Station	Winter Cal Freq
Barometric Pressure	mmHG		Bi-weekly	☐	
Gage Depth	Feet		Bi-weekly	☐	
TDG Pressure	mmHG		Bi-weekly	☐	
Water Temperature	Degrees Celcius		Bi-weekly	☐	

Station Name *JHAW* ***Date Est*** *1995* ***CROHMS ID*** *711*

Owner *US Army Corps of Engineers, Portland Distr*

Maint Resp *US Geological Survey*

Maint Seq *Bi-weekly*

Calib Resp *US Geological Survey*

Latitude *45° 42' 49*

Longitude *120° 42' 35*

River Nam *Columbia River*

River Mile *215*

Bank *Right Bank*

Description *Tailwater*

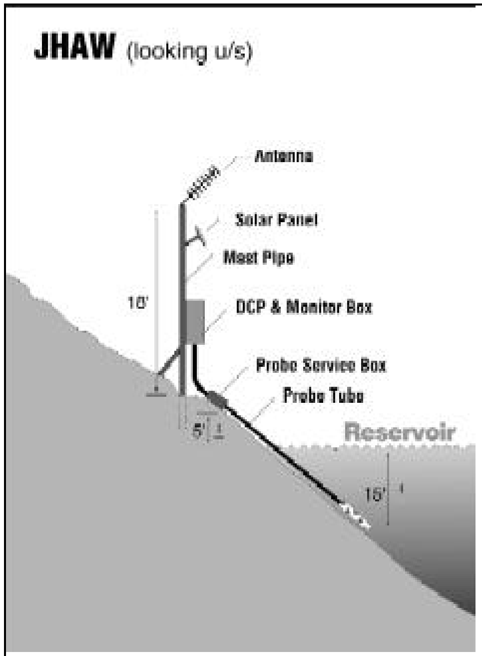
Drainage Are

Drainage Acreage: *226000*

Quad Map Name *Rufus*

Co-located with USGS? ☐

USGS ID



Parameter	*Unit*	*Type of calibration*	*Summer Cal Freq*	*Winter Station*	*Winter Cal Freq*
TDG Pressure	mmHG		Bi-weekly	☐	
Water Temperature	Degrees Celcius		Bi-weekly	☐	
Barometric Pressure	mmHG		Bi-weekly	☐	
Gage Depth	Feet		Bi-weekly	☐	

Station Name *LEWI* **Date Est** *1996* **CROHMS ID** *1277* **Maint Resp** *HDR*

Owner *US Army Corps of Engineers, Walla Walla* **Latitude** *46° 26' 06* **Maint Seq** *Bi-weekly*

Longitude *116° 57' 36* **Calib Resp** *HDR*

River Nam *Clearwater River*

River Mile *4*

Bank *Right Bank*

Description *River*

Drainage Are

Drainage Acreage: *93400*

Quad Map Name

Co-located with USGS? ☐

USGS ID *13343000*

Parameter	*Unit*	*Type of calibration*	*Summer Cal Freq*	*Winter Station*	*Winter Cal Freq*
TDG Pressure	mmHG		Bi-weekly	☐	
Water Temperature	Degrees Celcius		Bi-weekly	☐	
Barometric Pressure	mmHG		Bi-weekly	☐	

Station Name *LGNW* ***Date Est*** *1990* ***CROHMS ID*** *1202* ***Maint Resp*** *HDR*

Owner *US Army Corps of Engineers, Walla Walla* ***Latitude*** *46° 39' 58* ***Maint Seq*** *Bi-weekly*

Longitude *117° 26' 18* ***Calib Resp*** *HDR*

River Nam *Snake River*

River Mile *107*

Bank *Right Bank*

Description *Tailwater*

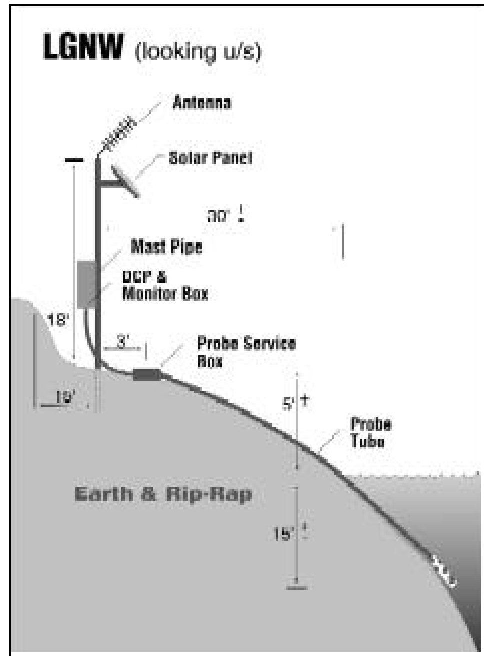
Drainage Are

Drainage Acreage: *103500*

Quad Map Name *Almota, Washingt*

Co-located with USGS? ☐

USGS ID *13343595*



Parameter	*Unit*	*Type of calibration*	*Summer Cal Freq*	*Winter Station*	*Winter Cal Freq*
Water Temperature	Degrees Celcius		Bi-weekly	☑	
Dissolved Oxygen	mg/L		Bi-weekly	☑	
Barometric Pressure	mmHG		Bi-weekly	☑	
TDG Pressure	mmHG		Bi-weekly	☑	

Station Name *LGS* **Date Est** *1984* **CROHMS ID** *1118* **Maint Resp** *HDR*

Owner *US Army Corps of Engineers, Walla Walla* **Latitude** *46° 35' 05* **Maint Seq** *Bi-weekly*

Longitude *118° 01' 32* **Calib Resp** *HDR*

River Nam *Snake River*

River Mile *70*

Bank *Mid-River*

Description *Forebay*

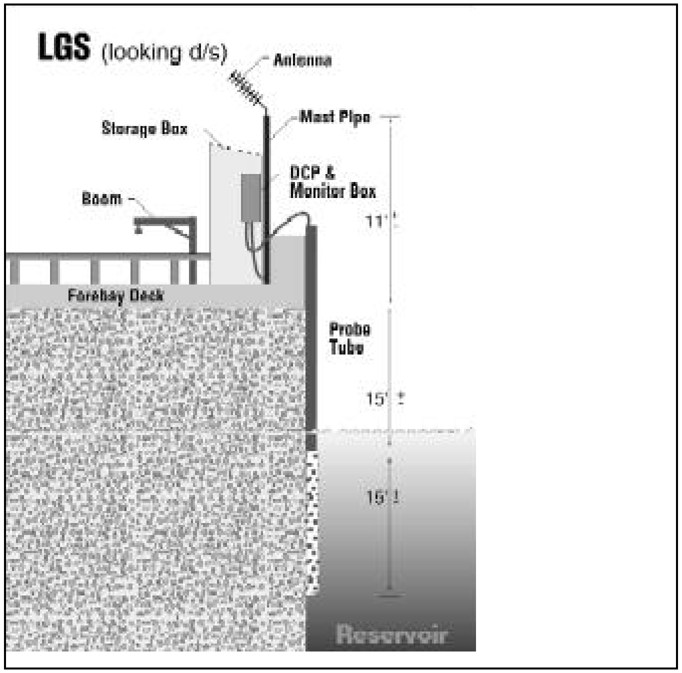
Drainage Are

Drainage Acreage: *103900*

Quad Map Name *Starbuck East, Wa*

Co-located with USGS? ☐

USGS ID *13343855*



Parameter	Unit	Type of calibration	Summer Cal Freq	Winter Station	Winter Cal Freq
Barometric Pressure	mmHG		Bi-weekly	☐	
TDG Pressure	mmHG		Bi-weekly	☐	
Dissolved Oxygen	mg/L		Bi-weekly	☐	
Water Temperature	Degrees Celcius		Bi-weekly	☐	

Station Name *LGSW* **Date Est** *1990* **CROHMS ID** *1114* **Maint Resp** *HDR*

Owner *US Army Corps of Engineers, Walla Walla*

Maint Seq *Bi-weekly*

Calib Resp *HDR*

Latitude *46° 34' 59*

Longitude *118° 02' 31*

River Nam *Snake River*

River Mile *69*

Bank *Right Bank*

Description *Tailwater*

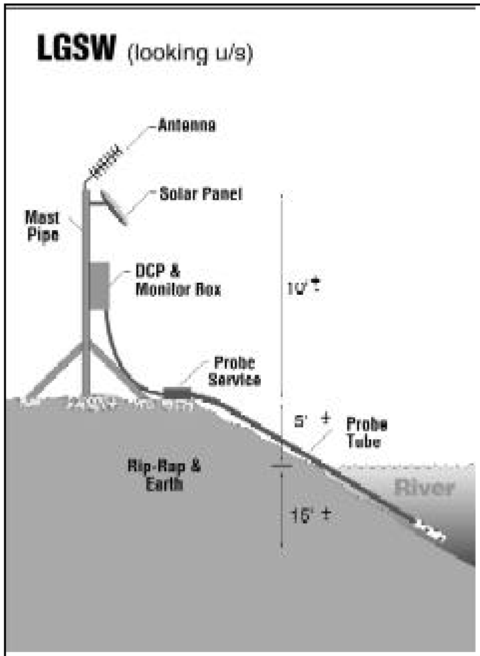
Drainage Are

Drainage Acreage: *103900*

Quad Map Name *Starbuck East, Wa*

Co-located with USGS? ☐

USGS ID *13343860*



Parameter	*Unit*	*Type of calibration*	*Summer Cal Freq*	*Winter Station*	*Winter Cal Freq*
Water Temperature	Degrees Celcius		Bi-weekly	☐	
Barometric Pressure	mmHG		Bi-weekly	☐	
Dissolved Oxygen	mg/L		Bi-weekly	☐	
TDG Pressure	mmHG		Bi-weekly	☐	

Station Name *LMN* **Date Est** *1984* **CROHMS ID** *1018*

Owner *US Army Corps of Engineers, Walla Walla*

Maint Resp *HDR*

Maint Seq *Bi-weekly*

Calib Resp *HDR*

Latitude *46° 33' 47*

Longitude *118° 32' 14*

River Nam *Snake River*

River Mile *42*

Bank *Mid-River*

Description *Forebay*

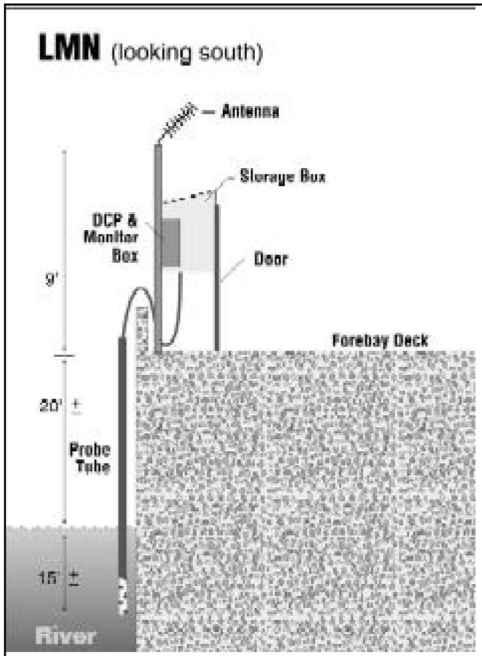
Drainage Are

Drainage Acreage: *108500*

Quad Map Name *Lower Monumenta*

Co-located with USGS? ☐

USGS ID *13352595*

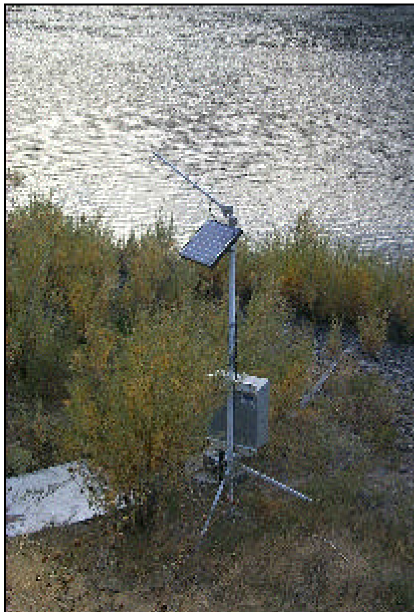


Parameter	*Unit*	*Type of calibration*	*Summer Cal Freq*	*Winter Station*	*Winter Cal Freq*
Barometric Pressure	mmHG		Bi-weekly	☐	
Water Temperature	Degrees Celcius		Bi-weekly	☐	
Dissolved Oxygen	mg/L		Bi-weekly	☐	
TDG Pressure	mmHG		Bi-weekly	☐	

Station Name *LMNW* **Date Est** *1990* **CROHMS ID** *1003* **Maint Resp** *HDR*

Owner *US Army Corps of Engineers, Walla Walla* **Latitude** *46° 33' 13* **Maint Seq** *Bi-weekly*

Longitude *118° 32' 51* **Calib Resp** *HDR*



River Nam *Snake River*

River Mile *41*

Bank *Left Bank*

Description *Tailwater*

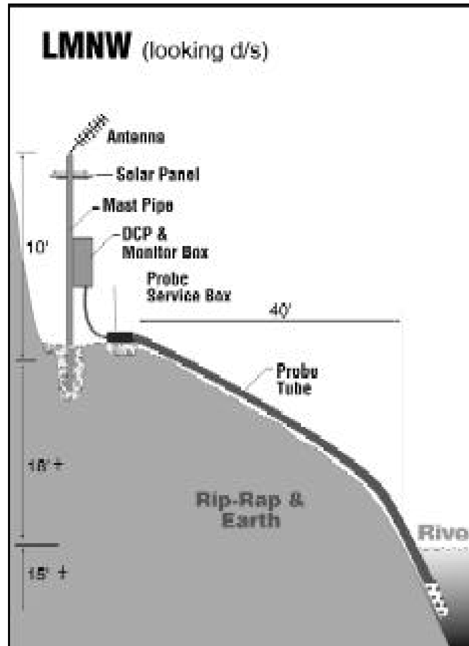
Drainage Are

Drainage Acreage: *108500*

Quad Map Name *Lower Monumenta*

Co-located with USGS? ☐

USGS ID *13352600*



Parameter	Unit	Type of calibration	Summer Cal Freq	Winter Station	Winter Cal Freq
Dissolved Oxygen	mg/L		Bi-weekly	☐	
Barometric Pressure	mmHG		Bi-weekly	☐	
Water Temperature	Degrees Celcius		Bi-weekly	☐	
TDG Pressure	mmHG		Bi-weekly	☐	

Station Name *LWG* **Date Est** *1984* **CROHMS ID** *1205* **Maint Resp** *HDR*

Owner *US Army Corps of Engineers, Walla Walla* **Maint Seq** *Bi-weekly*

Calib Resp *HDR*

Latitude *46° 39' 33*

Longitude *117° 25' 30*

River Nam *Snake River*

River Mile *108*

Bank *Left Bank*

Description *Forebay*

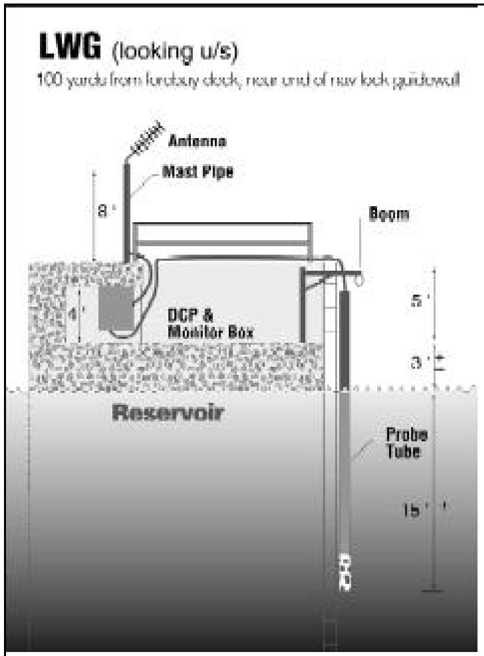
Drainage Are

Drainage Acreage: *103500*

Quad Map Name *Almota, Washingt*

Co-located with USGS? ☐

USGS ID *13343590*



Parameter	*Unit*	*Type of calibration*	*Summer Cal Freq*	*Winter Station*	*Winter Cal Freq*
Dissolved Oxygen	mg/L		Bi-weekly	☑	
Water Temperature	Degrees Celcius		Bi-weekly	☑	
TDG Pressure	mmHG		Bi-weekly	☑	
Barometric Pressure	mmHG		Bi-weekly	☑	

Station Name *MCPW* **Date Est** *1990* **CROHMS ID** *805* **Maint Resp** *HDR*

Owner *US Army Corps of Engineers, Walla Walla* **Latitude** *45° 56' 00* **Maint Seq** *Bi-weekly*

Longitude *119° 19' 30* **Calib Resp** *HDR*

River Nam *Columbia River*

River Mile *291*

Bank *Right Bank*

Description *Tailwater*

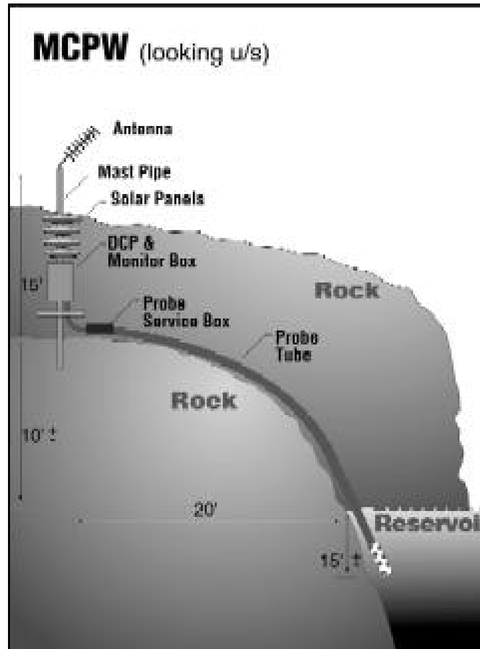
Drainage Are

Drainage Acreage: *214000*

Quad Map Name *Umatilla, Oregon-*

Co-located with USGS? ☐

USGS ID *14019240*

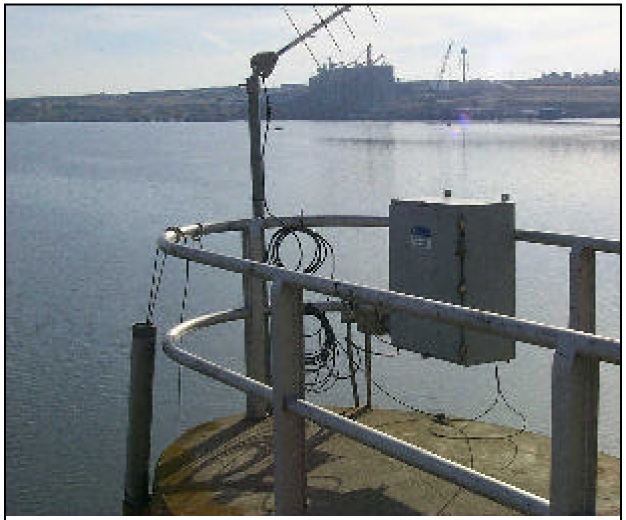


Parameter	*Unit*	*Type of calibration*	*Summer Cal Freq*	*Winter Station*	*Winter Cal Freq*
Dissolved Oxygen	mg/L		Bi-weekly	☑	
Water Temperature	Degrees Celcius		Bi-weekly	☑	
Barometric Pressure	mmHG		Bi-weekly	☑	
TDG Pressure	mmHG		Bi-weekly	☑	

Station Name *MCQO* **Date Est** *1986* **CROHMS ID** *820* **Maint Resp** *HDR*

Owner *US Army Corps of Engineers, Walla Walla* **Latitude** *45° 55' 58* **Maint Seq** *Bi-weekly*

Longitude *119° 17' 43* **Calib Resp** *HDR*



River Nam *Columbia River*

River Mile *292*

Bank *Left Bank*

Description *Forebay*

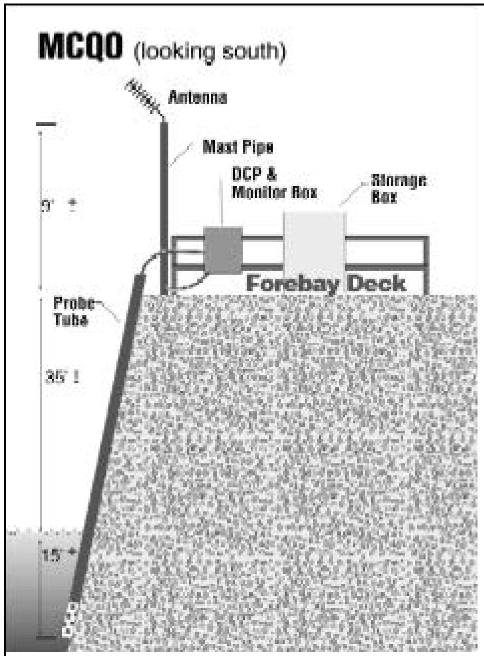
Drainage Are

Drainage Acreage: *214000*

Quad Map Name *Umatilla, Oregon-*

Co-located with USGS? ☐

USGS ID *14019200*



Parameter	*Unit*	*Type of calibration*	*Summer Cal Freq*	*Winter Station*	*Winter Cal Freq*
Water Temperature	Degrees Celcius		Bi-weekly	☑	
Barometric Pressure	mmHG		Bi-weekly	☑	
TDG Pressure	mmHG		Bi-weekly	☑	
Dissolved Oxygen	mg/L		Bi-weekly	☑	

Station Name *MCQW* **Date Est** *1985* **CROHMS ID** *814* **Maint Resp** *HDR*

Owner *US Army Corps of Engineers, Walla Walla* **Maint Seq** *Bi-weekly*

Calib Resp *HDR*

Latitude *45° 56' 25*

Longitude *119° 17' 47*

River Nam *Columbia River*

River Mile *292*

Bank *Right Bank*

Description *Forebay*

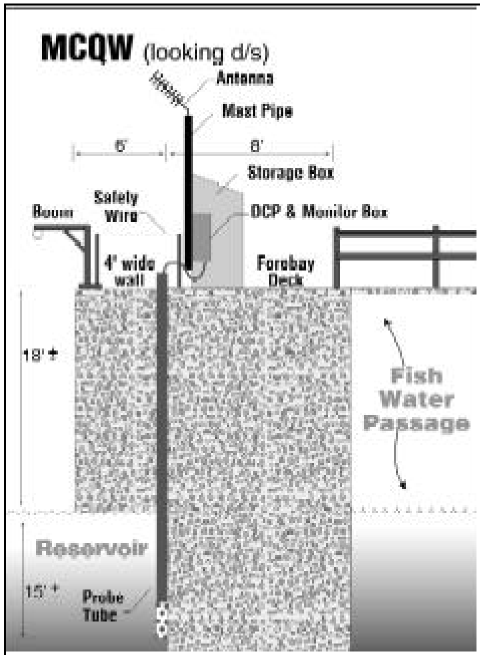
Drainage Are

Drainage Acreage: *214000*

Quad Map Name *Umatilla, Oregon-*

Co-located with USGS? ☐

USGS ID *12514400*



Parameter	Unit	Type of calibration	Summer Cal Freq	Winter Station	Winter Cal Freq
Dissolved Oxygen	mg/L		Bi-weekly	☑	
Barometric Pressure	mmHG		Bi-weekly	☑	
TDG Pressure	mmHG		Bi-weekly	☑	
Water Temperature	Degrees Celcius		Bi-weekly	☑	

Station Name *PAQW* **Date Est** *1998* **CROHMS ID** *2002* **Maint Resp** *HDR*

Owner *US Army Corps of Engineers, Walla Walla* **Latitude** *46° 13' 32* **Maint Seq** *Bi-weekly*

Longitude *119° 07' 25* **Calib Resp** *HDR*

River Nam *Columbia River*

River Mile

Bank *Left Bank*

Description *River*

Drainage Are

Drainage Acreage: *103000*

Quad Map Name *Pasco, Washingto*

Co-located with USGS? ☐

USGS ID

Parameter	Unit	Type of calibration	Summer Cal Freq	Winter Station	Winter Cal Freq
Dissolved Oxygen	mg/L		Bi-weekly	☑	
Water Temperature	Degrees Celcius		Bi-weekly	☑	
Barometric Pressure	mmHG		Bi-weekly	☑	
TDG Pressure	mmHG		Bi-weekly	☑	

Station Name *PEKI* **Date Est** *1996* **CROHMS ID** *1308* **Maint Resp** *HDR*

Owner *US Army Corps of Engineers, Walla Walla* **Latitude** *46° 32' 26* **Maint Seq** *Bi-weekly*

Longitude *116° 23' 31* **Calib Resp** *HDR*

River Nam *Clearwater River*

River Mile *36*

Bank *Left Bank*

Description *River*

Drainage Are

Drainage Acreage: *8040*

Quad Map Name *Southwick, Idaho*

Co-located with USGS? ☑

USGS ID *13341050*

Parameter	Unit	Type of calibration	Summer Cal Freq	Winter Station	Winter Cal Freq
Water Temperature	Degrees Celcius		Bi-weekly	☐	
TDG Pressure	mmHG		Bi-weekly	☐	
Barometric Pressure	mmHG		Bi-weekly	☐	
Dissolved Oxygen	mg/L		Bi-weekly	☐	

Station Name *SKAW* **Date Est** *1994* **CROHMS ID** *401*

Owner *US Army Corps of Engineers, Portland Distr*

Maint Resp *US Geological Survey*

Maint Seq *Bi-weekly*

Calib Resp *US Geological Survey*

Latitude *45° 36' 51*

Longitude *122° 02' 22*

River Nam *Columbia River*

River Mile *140*

Bank *Right Bank*

Description *Tailwater*

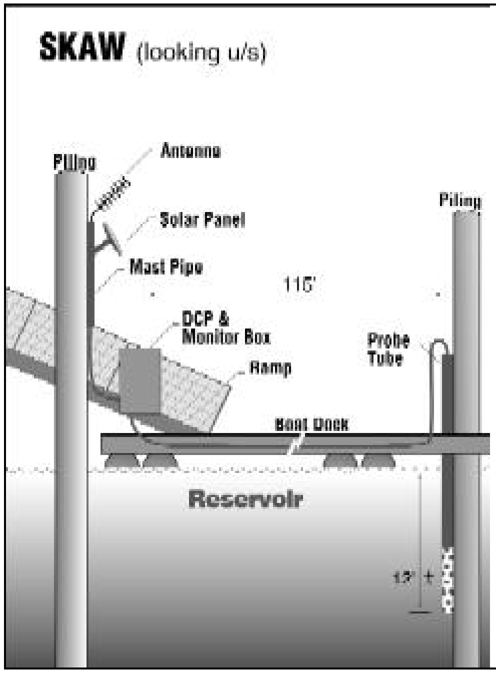
Drainage Are

Drainage Acreage: *240000*

Quad Map Name *Multnomah Falls*

Co-located with USGS? ☐

USGS ID



Parameter	Unit	Type of calibration	Summer Cal Freq	Winter Station	Winter Cal Freq
Water Temperature	Degrees Celcius		Bi-weekly	☐	
Gage Depth	Feet		Bi-weekly	☐	
TDG Pressure	mmHG		Bi-weekly	☐	
Barometric Pressure	mmHG		Bi-weekly	☐	

Station Name *TDA* **Date Est** *1984* **CROHMS ID** *3700*

Owner *US Army Corps of Engineers, Portland Distr*

Latitude *45° 37' 12*

Longitude *121° 07' 12*

River Nam *Columbia River*

River Mile *192*

Bank *Left Bank*

Description *Forebay*

Drainage Are

Drainage Acreage: *237000*

Quad Map Name *The Dalles South*

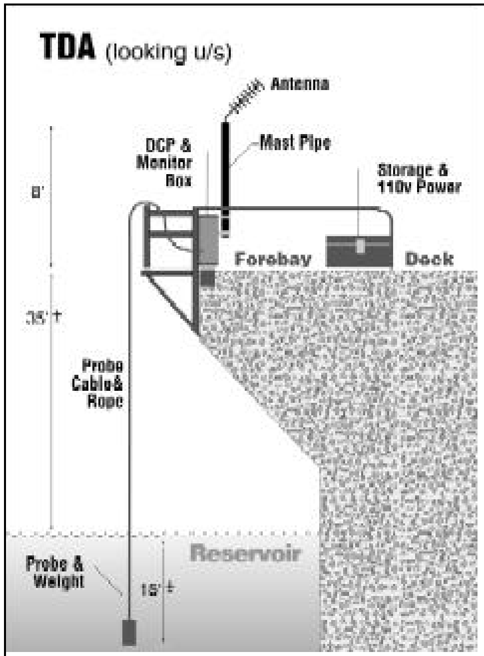
Co-located with USGS? ☐

USGS ID

Maint Resp *US Geological Survey*

Maint Seq *Bi-weekly*

Calib Resp *US Geological Survey*



Parameter	Unit	Type of calibration	Summer Cal Freq	Winter Station	Winter Cal Freq
TDG Pressure	mmHG		Bi-weekly	☐	
Gage Depth	Feet		Bi-weekly	☐	
Barometric Pressure	mmHG		Bi-weekly	☐	
Water Temperature	Degrees Celcius		Bi-weekly	☐	

Station Name TDDO **Date Est** 1996 **CROHMS ID** 522

Maint Resp US Geological Survey

Maint Seq Bi-weekly

Calib Resp US Geological Survey

Owner US Army Corps of Engineers, Portland Distr

Latitude 45° 36' 27

Longitude 121° 10' 20

River Nam Columbia River

River Mile 190

Bank Left Bank

Description Tailwater

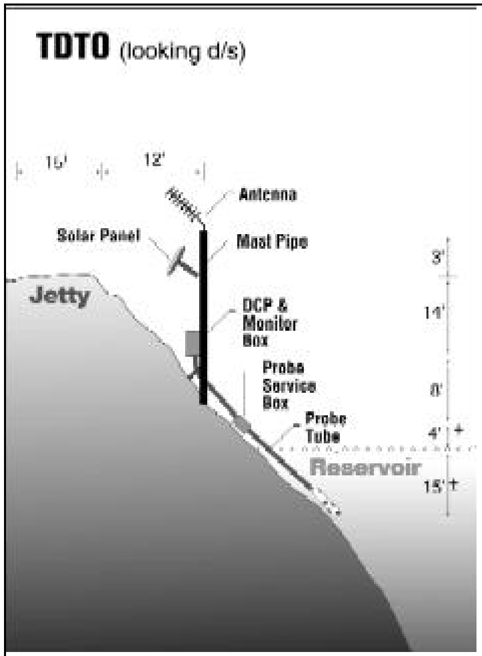
Drainage Are

Drainage Acreage: 237000

Quad Map Name The Dalles South

Co-located with USGS? ☐

USGS ID



Parameter	Unit	Type of calibration	Summer Cal Freq	Winter Station	Winter Cal Freq
Water Temperature	Degrees Celcius		Bi-weekly	☐	
Barometric Pressure	mmHG		Bi-weekly	☐	
Gage Depth	Feet		Bi-weekly	☐	
TDG Pressure	mmHG		Bi-weekly	☐	

Station Name *WRNO* **Date Est** *1984* **CROHMS ID** *403*

Owner *US Army Corps of Engineers, Portland Distr*

Maint Resp *US Geological Survey*

Maint Seq *Bi-weekly*

Calib Resp *US Geological Survey*

Latitude *45° 36' 30*

Longitude *122° 02' 14*

River Nam *Columbia River*

River Mile *140*

Bank *Left Bank*

Description *Tailwater*

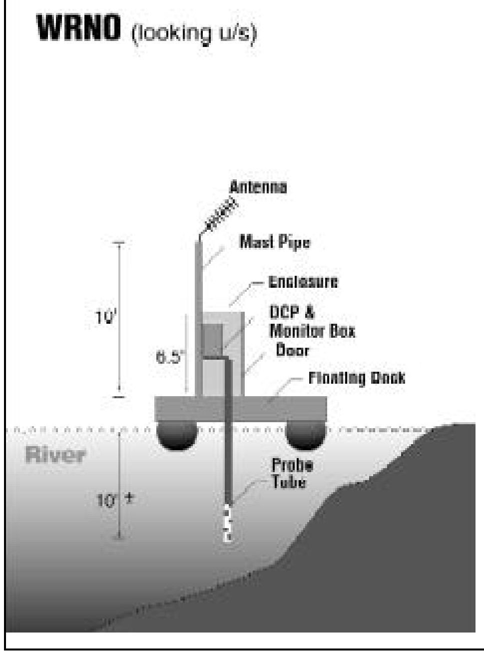
Drainage Are

Drainage Acreage: *240000*

Quad Map Name *Multnomah Falls*

Co-located with USGS? ☐

USGS ID



Parameter	Unit	Type of calibration	Summer Cal Freq	Winter Station	Winter Cal Freq
Gage Depth	Feet		Bi-weekly	☑	Tri-weekly
Water Temperature	Degrees Celcius		Bi-weekly	☑	Tri-weekly
TDG Pressure	mmHG		Bi-weekly	☑	Tri-weekly
Barometric Pressure	mmHG		Bi-weekly	☑	Tri-weekly

Appendix B
Plan of Action

CORPS OF ENGINEERS PLAN OF ACTION FOR DISSOLVED GAS MONITORING IN 2000

INTRODUCTION

This Plan of Action for 2000 summarizes the role and responsibilities of the Corps of Engineers as they relate to dissolved gas monitoring, and identifies channels of communication with other cooperating agencies and interested parties. The Plan summarizes what to measure, how, where, and when to take the measurements and how to analyze and interpret the resulting data. It also provides for periodic review and alteration or redirection of efforts when monitoring results and/or new information from other sources justifies a change. Some information on the complementary activities of other participating agencies is provided at the end of this document.

GENERAL APPROACH

The total dissolved gas (TDG) monitoring program consists of a range of activities designed to provide management information about dissolved gas and spill conditions. These activities include time-series measurements, data analysis, synthesis and interpretation, and calibration of numerical models. Four broad categories of objectives are involved:

1) data acquisition, to provide decision-makers with synthesized and relevant information to control dissolved gas supersaturation on a real-time basis,
2) real-time monitoring, to ascertain where project release water quality stands relative to existing state dissolved gas standards and federal criteria;
3) trend monitoring, to identify long-term changes in basin wide dissolved gas saturation levels resulting from water management decisions; and
4) model refinement, to enhance predictive capability of existing models used to evaluate management objectives.

Portland, Seattle and Walla Walla Districts will continue to assume direct responsibilities for TDG monitoring at their respective projects, including data collection, transmission, and analysis and reporting. The Division's Reservoir Control Center (RCC) will coordinate this activity with the Districts and other State and Federal agencies and private parties as needed to insure the information received meet all real-time operational and regulatory requirements. Districts and Division roles and functions are described in more detail in later sections of this document.

The Corps considers TDG monitoring a high priority activity with considerable potential for adversely affecting reservoir operations and ongoing regional efforts to protect aquatic biota. It will make all reasonable efforts toward achieving at least a data quality and reliability level comparable to that provided in 1999.

Furthermore, the Corps believes it is important to maintain a two-way communication between those conducting the monitoring and the users of monitoring information. These interactions give decision-makers and managers an understanding of the limitations of monitoring and, at the same time, provide the technical staff with an understanding of what questions should be answered. Therefore, comments and recommendations received from users were and continue to be very useful in establishing monitoring program priorities and defining areas requiring special attention.

DISTRICTS/DIVISION RESPONSIBILITIES

Portland, Seattle and Walla Walla Districts Functions. Portland, Seattle and Walla Walla Districts will perform all the activities required at their TDG monitoring sites. Data will be collected and transmitted from those sites systematically and without interruption to the Columbia River Operational Hydromet Management System (CROHMS) (or any alternate database as may be specified). Normal monitoring season will be from 1 April through 15 September for all stations except Bonneville and the stations below Bonneville. Because of the Spring Creek hatchery release, monitoring for Bonneville and stations below Bonneville will be from 10 March through 15 September. Winter monitoring, where applicable, will be at least from 15 December through 15 March.

District responsibilities include but are not limited the following tasks:

- preparing annual monitoring plan of action and schedule
- procuring data collection/transmission instruments
- preparing and awarding equipment and service contracts
- performing initial instrument installation and testing
- setting up permanent monitoring installations, if requested
- relocating existing stations, if warranted
- collecting and transmitting TDG data to CROHMS
- reviewing data for early detection of instrument malfunction
- making periodic service and maintenance calls once every 2-3 weeks
- providing emergency service calls as needed and/or when so notified
- performing special TDG measurements, if needed
- keeping records of instrument calibration and/or adjustments
- retrieving, servicing, and storing instruments at the end of the season
- making final data correction and posting in separate data base
- performing data analysis to establish/strengthen spill vs. TDG relationship
- preparing an annual activity report
- document and report QA/QC performance

All three Districts will also be responsible for (1) preparing an annual report on instrument performances, and (2) providing the necessary material including test and data analyses, charts, maps, etc. for incorporation in the Corps' Annual TDG Report, which will be finalized by the Division. Additional monitoring at selected locations may be required on an as needed basis and as possible based on available funding. Dissemination of data to outside users will remain a Division responsibility to avoid duplication and uncoordinated service.

Division's Functions. The Division will be responsible for overall coordination of the TDG monitoring program with the Districts, other State and Federal agencies and cooperating parties. The Chief of the Water Quality Section, CENWD-NP-ET-WR, is the designated TDG Division Program Coordinator. S/he will report through the chain of command through Chief, Reservoir Control Center and Chief, Water Management Division to Director, Engineering & Technical Services Directorate. S/he will consult as needed with interested staff in Planning Division, Pacific Salmon Coordination Office, Construction-Operations Division, and others.

The Division TDG Program Coordinator will provide overall guidance to his District counterparts to ensure that the monitoring program is carried out in accordance with the plan outlined in this document, including close adherence to a general schedule and operating QA/QC protocols. S/he will be the main point of contact for all technical issues related to the TDG monitoring at Corps projects. S/he will refer problems of common regional interest to relevant forums such as the EPA/NMFS Water Quality Team (WQT) for peer review and open discussion. S/he will facilitate final decision-making on technical issues based on all relevant input from interested parties.

The Division TDG Program Coordinator will meet with his District counterparts in January to discuss and firm up detailed implementation plan and schedule for the current year. Discussion will cover monitoring sites, equipment, data collection and transmission procedures, service and maintenance, budget, etc. A set of specific performance standards will be jointly prepared as a basis for reviewing and monitoring District performances. A post-season review meeting will be held annually to provide a critique of the operations and identify areas needing changes and/or improvements.

2000 ACTION PLAN

The 2000 Action Plan consists of the usual seven phases observed in previous years, plus winter monitoring. These phases are as follows:

(1) Program start-up;
(2) Instrument Installation;
(3) In-season Monitoring and Problem Fixing;
(4) Instrument Removal and Storage;
(5) Winter Monitoring
(6) Data Compilation, Analysis and Storage;
(7) Program Evaluation and Report; and
(8) Special Field Studies

The Plan of Action for all three Districts is essentially the same as in 1999, with the exception some QA/QC modifications.

Portland District will continue to use the USGS to conduct their TDG monitoring. Walla Walla District water quality staff may contract out some of the routine instrument calibration responsibilities in 2000. They will continue to operate much of their system by themselves. Seattle District will continue to contract with Common Sensing, Inc. to conduct their routine calibration of TDG equipment. In general the 1999 plan is as follows.

Phase 1: Program Start-Up

Responsible parties (See Table 1) will be invited for a follow-up coordination meeting some time in January for final discussions on the plan of action. This will ensure a good mutual understanding of the most current objectives of the dissolved gas monitoring program, including data to be collected, instrument location, procedures to be used, special requirements, etc. The draft plan will be presented for peer review at a January meeting of the WQT.

All three Districts will ensure that adequate funding is available for 2000 monitoring activities. Portland District, having decided to continue to use the service of the USGS in 2000, will prepare the necessary MIPRs to secure those services and provide for rental and associated maintenance of the USGS's Sutron data collection platforms. Walla Walla District will review their equipment inventory and proceed with the necessary orders for new TDG instruments and DCPs, if applicable. Seattle will renew their contractual arrangements as needed for the operation of the Chief Joseph and Libby stations.

All maintenance and service contracts should be completed at least two weeks before the instruments are installed in the field. Where applicable, the Districts will ensure that real estate agreements and right of entry are finalized between the landowners and the Corps. All paper work for outside contracting will be completed no later than 31 January.

To date, the districts have been initiating the MIPR processes to continue contracts through the 1999-2000 winter monitoring season and the 2000-monitoring season. Districts and division have been updating the QA/QC protocols. Walla Walla District is planning to install temperature loggers in several Lower Snake reservoirs. Temperature loggers have already been placed in Dworshak Reservoir. Walla Walla may be changing their current transmission systems from LAN connection-based transmission to GOES satellite transmission

Discussions between districts, division and contractors are expected to continue through January, at which time a final plan of action will be produced. It is also understood that the following entities will continue to operate their monitoring instruments in 2000:

- U.S. Bureau of Reclamation, below Hungry Horse, at the International Boundary and above and below Grand Coulee Dam;
- Mid-Columbia PUDs (Douglas, Chelan and Grant Counties), above and below all five PUD dams on the Columbia River; and
- Idaho Power Company, in the Hells Canyon area (as part of its Federal Energy Regulatory Commission's license renewal requirement).

Phase 2: Instrument Installation

Instruments to be installed and their assigned locations are listed in Table 2 and shown in Figure 1. Some of them are already in place for the 1999-2000 winter monitoring. The Corps network will essentially remain the same as in 1999, except for the following. Walla Walla District has installed temperature monitors in the upper portions of the Dworshak pool and is considering the installation of temperature monitors in the forebays of McNary, Ice Harbor and Lower Granite project. These stations would consist of eight sensors in ten-foot vertical increments collecting data every two hours. The district is discussing the cost feasibility of real-time transmission of this information versus manual downloading. Walla Walla may keep the Anatone and Pasco sites in operation over the winter measuring temperature only. Portland District has removed the Kalama and Wauna Mills sites (as of winter 1998-9).

As before, the station below Libby Dam will only be activated if spill for flood control at the project becomes likely.

All instruments are scheduled to have been in place and duly connected to their Sutron or Zeno DCP's no later than 10 March at Bonneville and downstream stations, and no later than 1 April at all other stations. If needed, the station below Libby will be reactivated in May or at least two weeks before the start of flow releases for white sturgeon. Monitoring stations below Bonneville are scheduled to be in place first, prior to the release of Spring Creek Hatchery fish.

Corps stations that remain in service during the 1999-2000 winter will continue their operation with minimum interruption into the spring, following the necessary instrument service and maintenance check-up. These stations include the following: Dworshak tailwater, Lower Granite forebay and tailwater, Ice Harbor forebay and tailwater, McNary forebay (Oregon and Washington sides) and tailwater, Bonneville forebay, and Warrendale. An assessment of monitoring site integrity will be conducted; any damages that may have occurred over the winter will be fixed before proceeding on to calibration and testing. Selected project personnel may be requested to assist on this task as needed.

Phase 3: In-season Monitoring and Problem Fixing

Actual data collection and transmission will start prior to the first Spring Creek Hatchery release, but no later than 15 March for stations below Bonneville, and no later than 1 April for the remainder of the monitoring network. Exact starting dates will be coordinated with the Corps' Reservoir Control Center (CENWD-NP-ET-WR), project biologists and cooperating agencies, based on run-off, spill, and fish migration conditions.

The following data will be collected approximately every hour:

WC, Water Temperature (^{o}C)
BH, Barometric Pressure (mm of Hg)
NT, Total Dissolved Gas Pressure (mm of Hg)

Oxygen pressure and calculated nitrogen pressure parameters are currently collected at Walla Walla stations and at one Seattle District station.

OP, Dissolved Oxygen Pressure (mm of Hg)
NP, Nitrogen + Argon Pressure (mm of Hg)

Data will be collected at least hourly and transmitted at least every four hours. If feasible, the previous 12 hours of data will also be sent to improve the capability of retrieving any data that may have been lost during the preceding transmission. For Portland and Seattle Districts, data transmission will be done via the GOES Satellite, to the Corps' ground-receive station in Portland. After decoding, all data will be stored in the CROHMS database. Per their contract with Portland District, the USGS is planning to have the satellite data going into CROHMS and ADAPS (internal to the USGS) simultaneously to allow for some pre-screening. The Walla Walla District will transmit their data hourly to CROHMS and the Walla Walla District's Home page on the Internet. Transmission will be through routes other than the GOES satellite.

Given their direct relevance to fish mortality, the first three parameters (WC, BH and NT) will be collected on a first priority basis. At the 1998 annual post-season review, a suggestion was made to extend high monitoring priority to Dissolved Oxygen in known oxygen-deficient areas. During the 1999 annual post-season review, attendants were not convinced that oxygen should only be measured at oxygen limited locations because oxygen pressure data answers questions about nitrogen content of saturated waters. No resolution was reached, however if oxygen is measured, managers are encouraged to follow adequate QA/QC measures to ensure that the data gathered is valid.

Given the problems with calibration at the John Day tailwater station in 1999, and given the uncertainties of the deflector performance as it relates to TDG production, a second or “redundant” instrument will be placed in the same monitoring pipe as the first instrument during the 2000-monitoring season. Both instruments will transmit to CROHMS real-time.

Daily reports summarizing TDG and related information will be posted on the Technical Management Team's home page. To the extent feasible, the measured TDG data will be compared with model predicted values so that suspicious values can be flagged and/or discarded before they are released. Data filtering through other methods will also be made. Information provided on the homepage will include the following data:

- Station Identifier
- Date and Time of the Probe Readings
- Water Temperature, °C
- Barometric Pressure, mm of Hg
- TDG Pressure, mm of Hg
- Calculated TDG Saturation Percent (%)
- Project Hourly Spill, Kcfs (QS)
- Project Total Hourly Outflow, Kcfs (QR)
- Number of Spillway Gates Open

Stop settings, if different from the numbers provided in the Fish Passage Plan, will also be given.

Reconciliation between data received to CROHMS will be made by the Reservoir Control Center staff based on the input from the field before the data are permanently stored in the Corps' Water Quality Data Base. Additional data posting in the Technical Management Team or Portland, Seattle and Walla Walla Districts' home page will continue.

Instrument reliability and accuracy will be monitored through the following basic QA/QC procedures, as discussed through the WQT technical workgroup.

- Calibrations of instruments will occur every two weeks
- Competent personnel (Corps or contractor) will visit monitoring site to check for and if necessary, fix site problems (probes clogging, leaking membranes, instruments out of calibration, etc.) and recalibrate the faulty instrument(s).
- Calibration will be accomplished using a primary standard (pressure gauge, hand-held barometer, etc). A secondary standard, such as a portable lab-calibrated instrument, will be used as needed to limit sampling precision uncertainty.
- TDG membranes will be changed every two weeks with a dry, functioning membrane.
- If an emergency visit is conducted, a redundant monitor will be placed in river during emergency visit to serve as a temporary back-up to field monitor.

If data recorded by the fixed sensors are different from those recorded during calibration procedure, appropriate corrections will be made to current as well as past data already stored in CROHMS as soon as possible. Significant and/or unusually large changes will be reported immediately to all customary users, including the Fish Passage Center.

Adequate inventory of spare instruments will be maintained to ensure that at least one backup monitor will be made available for deployment as necessary in each Corps District. A malfunctioning instrument will be repaired within 24 to 48 hours, depending on the remoteness of the instrument location and TDG conditions (weekends may require a longer response time). High priority will be placed on fixing a faulty instrument when TDG are or expected to be in excess of the current state standards.

Contractor and/or Corps staff will maintain TDG instruments. Instruments needing repairs that are beyond the staff's capability will be shipped to the manufacturer. In-house water quality and information management will do repairs of communication network staff. USGS Stennis Center (MS) staff will handle Service and repairs of the Sutron DCPs. Service and repairs of the Zeno DCPs will be performed by a contractor.

To better understand the physical process of dissolved gas distribution across the reservoirs and its dissipation along the various pools, selected transects studies will continue to be conducted on an as-time-permits basis. An additional objective for this activity is to be able to define how representative readings from current monitoring sites really are with respect to the entire river reach. Model runs using GASSPILL and other acceptable tools such as a Neural Network model or regression-based equations developed by the Waterway Experimental Station for the Gas Abatement Study will be performed as needed to define the range of expected/acceptable TDG levels under various spill conditions.

To help reduce response time in determining whether an emergency field visit is needed, the following decision-making model was developed by the WQT:

1) No emergency trips are made for the parameter of temperature or oxygen.

2) For gas and barometric pressure, if more than 25% of the hourly values are missing, then an emergency trip is needed.

3) If the difference in values between two consecutive stations is larger than 20 mm Hg for gas pressure, or 14 mm Hg for barometric pressure, then an emergency trip is triggered. Criterion 3 does not apply if:

a) there is a transient “spike” for a parameter.
b) if the higher-than-expected gas pressure value is associated with spill operations.

4) If gas parameters at a station do not fall within any of the WES generated/RCC generated gas production curves, are not caused from operational or structural changes, and these data persist for over 48 hours, then an emergency visit is triggered.

5) If there is uncertainty with an abnormal reading at a gas monitoring station that persists for more than 48 hours, the COE will notify TMT and WQT members as soon as possible via email. If the COE plans to change fish passage actions because of the uncertainty, it should notify both the TMT & WQT members of the proposed change. TMT members will determine whether or not a meeting or conference call is needed and advise the COE of this need. The COE will then convene a TMT meeting. Each state's fishery and water quality agencies will work together prior to any TMT meeting on this issue to balance and assure consistency of the proposed actions with fishery management requirements and state water quality standards.

Phase 4: Instrument Removal and Storage

Water quality monitors will be removed shortly after the end of the monitoring season (15 September) by Corps staff or the USGS, except for those that are slated for continued winter monitoring. Those removed will be serviced by the maintenance and service contractors and stored at a convenient location until the beginning of the next monitoring season. A selected number of monitors and spare DCPs will be available for off-season special monitoring activities upon request. Seattle District owns its Sutron DCPs, and maintains and stores them as needed.

Phase 5: Winter Monitoring.

The same few stations that were selected for winter operation in 1998-1999 will be retained for compliance monitoring in the following 1999-2000 winter. These included, at a minimum, stations located at International Boundary, Dworshak tailwater, Lower Granite forebay and tailwater, Ice Harbor forebay and tailwater, McNary forebay (Oregon and Washington) and tailwater, Bonneville forebay, and Warrendale. Anatone and Pasco stations will continue to monitor temperature over the winter season.

Phase 6: Data Compilation, Analysis and Storage

Time and resource permitting, Corps staff and contractors will fill data gaps, perform statistical analyses, and develop trends and relationships between spill and TDG saturation. Efforts will continue to be expanded on the calibration and application of GASSPILL (Dissolved Gas) and COLTEMP (Water Temperature) models, and finding ways to facilitate and/or improve user access to the TDG and TDG-related database. The GASSPILL model will be periodically modified to incorporate the latest findings brought about by the Gas Abatement Study. Regression-based models assembled by the University of Washington will also be used as appropriate. Possibly, the SYSTDG model (being developed by WES) will be available for in-season gas production predictions and screening. Data collected at and transmitted from all network stations will be ultimately stored at CENWD-NP-ET-WR, where they can be accessed through a data management system such as HEC-DSS.

Phase 7: Program Evaluation and Summary Report

An annual report will be prepared after the end of the normal (spring and summer) monitoring season to summarize the yearly highlights of the TDG monitoring program. It will include a general program evaluation of the adequacy and timeliness of the information received from the field, and how that information is used to help control TDG supersaturation and high water temperature in the Columbia River basin. Information on the performance of the instruments (including accuracy, precision and bias associated with each parameter) and the nature and extent of instrument failures will be documented. This summary should include statistics on data confidence limits. Division staff will prepare the Annual TDG Monitoring Report based on field input and other material provided by each District. This report will also contain suggestions and recommendations to improve the quality of the data during the FY2000 monitoring program.

The WQT has discussed the possibility of developing an independent peer review process to confirm data quality in-season and to summarize data quality post-season. This review process would likely be costly, so the group is currently compiling a firm outline of what the process would provide and how much it would cost. This action may be incorporated into the 2000-monitoring season.

Phase 8: Special Field Studies

As provided for in Phase 3, additional monitoring of dissolved gas saturation will be conducted on an as-needed basis. The current plan for additional monitoring includes transect measurements below selected dams to: 1) establish the relationship between various spill amounts and TDG saturation, and 2) plot TDG variations within a given cross-section of the river, especially a cross-section that includes a fixed monitoring station. Special consideration will continue to be made at evaluating improvements (or any other changes) to TDG levels brought about by the new flip-lips at John Day Dam. Efforts will also be expanded in learning more about dissolved gas supersaturation dissipation along the fish migration route, possibly using monitoring made from moving fish barges and deployment of self-contained wireless probes. These on-going efforts are expected to continue for several years.

COOPERATION WITH PARTICIPATING AGENCIES

The Bureau of Reclamation, Douglas County PUD, Chelan County PUD, and Grant County PUDs currently monitor for total dissolved gases at their mainstem projects. Until recently, these groups were not directly influenced by the listings of salmon and steelhead under the Endangered Species Act. Nonetheless, they have maintained a cooperative effort with the Corps in collecting and reporting total dissolved gas and related water quality parameters and in making this information available to the Corps for storage in their CROHMS database. Idaho Power Company is believed to have been collecting some TDG information in the Hells Canyon Complex, however, this information has not been as widely disseminated as the data from the rest of the TDG monitoring network. Following are the action plans for the cooperating agencies.

<u>Bureau of Reclamation.</u> Bureau of Reclamation TDG monitoring will continue at International Boundary and the Grand Coulee forebay and tailrace, and the Hungry Horse sites in 2000. Hourly data transmission to CROHMS will continue via the GOES satellite. In May 1998, the Grand Coulee forebay sensor was lowered to elevation 1193', 15' below minimum operating pool. This change was done to provide more representative water quality data of the impounded water released downstream via turbine intakes or spill outlets.

<u>Douglas County PUD.</u> TDG monitoring will continue at the forebay and tailrace of Wells Dam in 2000. Hourly data from both of these stations will continue to be sent to the Corps. Douglas Co. may be conducting their station calibrations on a more frequent basis in 2000, and are considering contracting this work out.

<u>Chelan County PUD.</u> The physical monitoring of TDG to be conducted in 2000 will be very similar to the monitoring conducted in 1999. Chelan will continue to monitor TDG in the forebay and tailrace of both Rocky Reach and Rock Island Dams. The PUD will continue to use Common Sensing monitors in the forebay and Hydrolab Datasonde 4s in the tailrace. Data will continue to arrive to the Corps hourly, and efforts will be made to repair malfunctioning probes within 48 hours. Monitoring instruments will be calibrated every three to four weeks or as necessary. Chelan will also continue to conduct weekly transects in the tailraces of both projects to validate the locations of the tailrace monitors and may institute some forebay transects to verify that forebay readings are representative of the conditions in the river at large.

<u>Grant County PUD.</u> TDG will continue to be monitored in the forebays and tailraces of both Wanapum and Priest Rapids Dams. Fixed site locations will not be changed and all probes will be calibrated before the season and every three to four weeks following. Hourly data will continue to be posted on the Grant Co. PUD website. The PUD will also continue weekly cross sectional monitoring at the four fixed monitoring stations in the forebay and tailraces of both projects. Calibration of the instruments was contracted out in 1999.

Table 1. List of Contact Persons in 2000

Project	Name	Position	Phone #	E-Mail
Internat'l Bndry., Hungry Horse, Grand Coulee	Dave Zimmer	Biologist/ Coordinator	(208) 378-5088	dzimmer@ pn.usbr.gov
	Norbert Cannon	Oversight	(208) 334-1540	ncannon@ pn.usbr.gov
	Jim Doty	Transmission	(208) 378-5272	jdoty@ pn.usbr.gov
Chief Joseph, Libby	Marian Valentine	Hydraulic Eng./ Coordinator	(206) 764-3543	marian.valentine @usace.army.mil
	Dave VanRijn	Oversight	(206) 764-6926	david.p.vanrijn@ usace.army.mil
	Ray Strode	Trouble-shooting	(206) 764-3529	ray.strode@ usace.army.mil
Wells (Douglas)	Rick Klinge	Biologist/ Coordinator	(509) 884-7191	rklinge@ televar.com
Rocky Reach, Rock Isl.(Chelan)	Robert MacDonald	Biologist/ Coordinator	(509) 663-8121	robertm@ televar.com
Wanapum, Priest Rapids (Grant)	Chris Carlson	Biologist/ Coordinator	(509) 754-3541 x2154	ccarlso@ gcpud.org
	Dee Chandler	Oversight/Data Management	(509) 754-3541	dchandl@ gcpud.org
Dworshak, Low. Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, Pasco, Anatone	Dave Reese	Biologist/ Coordinator	(509) 527-7279	david.l.reese@ usace.army.mil
	Gary Slack	Oversight	(509) 527-7636	gary.m.slack@ usace.army.mil
	Russ Heaton	Oversight	(509) 527-7282	russ.d.heaton@ usace.army.mil
John Day, The Dalles, Bonne-ville, Warrendale, Skamania,Camas /Washougal, Kalama, Wauna Mills	Jim Britton	Biologist/ Coordinator	(503) 808-4888	james.l.britton@ usace.army.mil
	Joe Rinella	USGS/Contract Coordinator	(503) 251-3278	jrinella@ usgs.gov
	Dwight Tanner	USGS/Oversight	(503) 251-3289	dqtanner@ usgs.gov
Division Pgm. Coordination	Dick Cassidy	Program Coordinator	(503) 808-3938	richard.a.cassidy @usace.army.mil
	Mary Todd Haight	Program Oversight	(503) 808-3939	mary.todd.haight @usace.army.mil

Table 2. 2000 Dissolved Gas Monitoring Network

STATION CODE	STATION NAME	OWNERS
CIBW*	US/Can Boundary	USBR
HGHW	Below HGH	USBR
FDRW	GCL Forebay	USBR
GCGW	GCL Tailwater	USBR
LIBM (#)	LIB Tailwater	NWS
CHJ	CHJ Forebay	NWS
CHQW	CHJ Tailwater	NWS
WEL	WEL Forebay	DOUGLAS CO.
WELW	WEL Tailwater	DOUGLAS CO
RRH	RRH Forebay	CHELAN CO.
RRDW	RRH Tailwater	CHELAN CO.
RIS	RIS Forebay	CHELAN CO.
RIGW	RIS Tailwater	CHELAN CO.
WAN	WAN Forebay	GRANT CO.
WANW	WAN Tailwater	GRANT CO.
PRD	PRD Forebay	GRANT CO.
PRXW	PRD Tailwater	GRANT CO.
PAQW	Col. Above Snake	NWW
DWQI*	DWR Tailwater	NWW
PEKI	Peck/Clearwater	NWW
LEWI	Lewiston/Clearwater	NWW
ANQW	Upper Snake at Anatone	NWW
LWG*	LWG Forebay	NWW
LGNW*	LWG TW	NWW
LGS	LGS Forebay	NWW
LGSW	LGS Tailwater	NWW
LMN	LMN Forebay	NWW
LMNW	LMN Tailwater	NWW
IHR*	IHR Forebay	NWW
IDSW*	IHR Tailwater	NWW
MCQW*	MCN FB/Wa	NWW
MCQO*	MCN FB/Or	NWW
MCPW*	MCN Tailwater	NWW
JDA	JDA Forebay	NWP
JHAW	JDA Tailwater	NWP
TDA	TDA Forebay	NWP
TDDO	TDA Tailwater	NWP
BON*	BON Forebay	NWP
WRNO*	Warrendale	NWP
SKAW	Skamania	NWP
CWMW	Camas	NWP

(#) during spill only (*) winter monitoring station USBR= U.S. Bureau of Reclamation NPP= Portland District NPS= Seattle District NPW = Walla Walla District LB=Left bank RB=Right bank MC=mid-channel

Figure 1. 2000 Dissolved Gas Monitoring Network

Appendix C

Section 1: Voluntary / Involuntary Spill

Section 2: Dworshak temperature releases

Voluntary / Involuntary Spill

The National Marine Fisheries (NMFS) 1995 Biological Opinion and 1998 Supplemental Biological Opinion outline spill programs for the mainstem Columbia and Snake Rivers. The spill program is identified as a means to pass migrant fish past projects with less exposure to the potential effects of turbines by spilling water through the project spill bays. During the spill season, April through September, the amount of water spilled at each project is based upon the guidance provided in the NMFS documents with in-season spill adjustments to maintain the Total Dissolved Gas (TDG) levels below the state Clean Water Act standards in the tailwaters and forebays.

During the remainder of the year the projects are operated with a focus on issues other than fish passage, such as power generation and flood control. The TDG levels in the mainstem Columbia and Snake Rivers are monitored. The projects are operated in a manner to not exceed the state standards, if possible. Typical situations where meeting state standards might not be possible would be during fall or winter rain events or spring run-off events when the river volume exceeds the project powerhouse capacity.

The following graphs contain data extracted from the Columbia River Operational Hydrologic and Meteorological System (CROHMS) along with calculated values for involuntary spill. This information was calculated and compiled by BPA. The definition for involuntary spill, total flow and total spill for these graphs is:

Involuntary Spill

- Equal to sum of flow (spill) above turbine capacity plus lack-of-market spill where lack-of-market spill is
    - Spilled water that could have been passed through the turbines to generate power if a load/market had existed for that additional generation.

Total Flow

- Total volume of water passing a project.
- Observed value retrieved from CROHMS.

Total Spill

- Volume of water passing a project through the spill bays.
- Observed value retrieved from CROHMS.

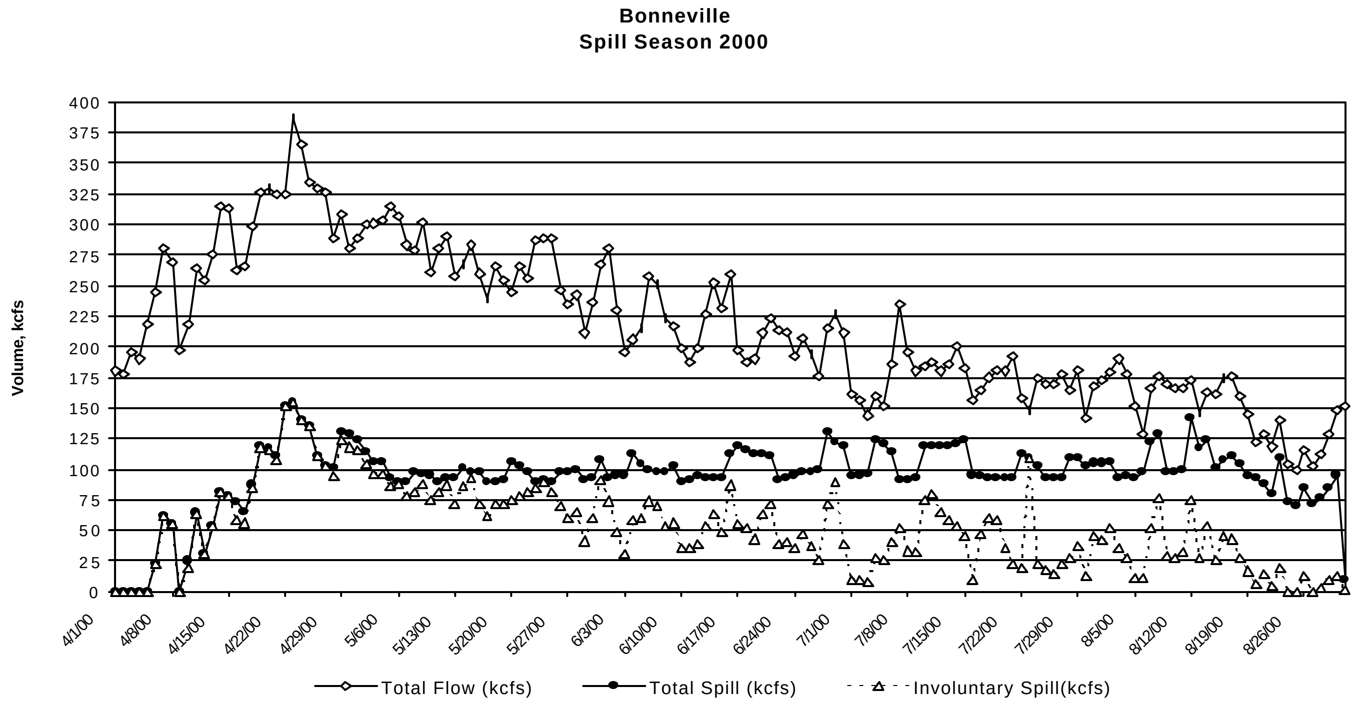


Figure 1 Bonneville – Involuntary Spill

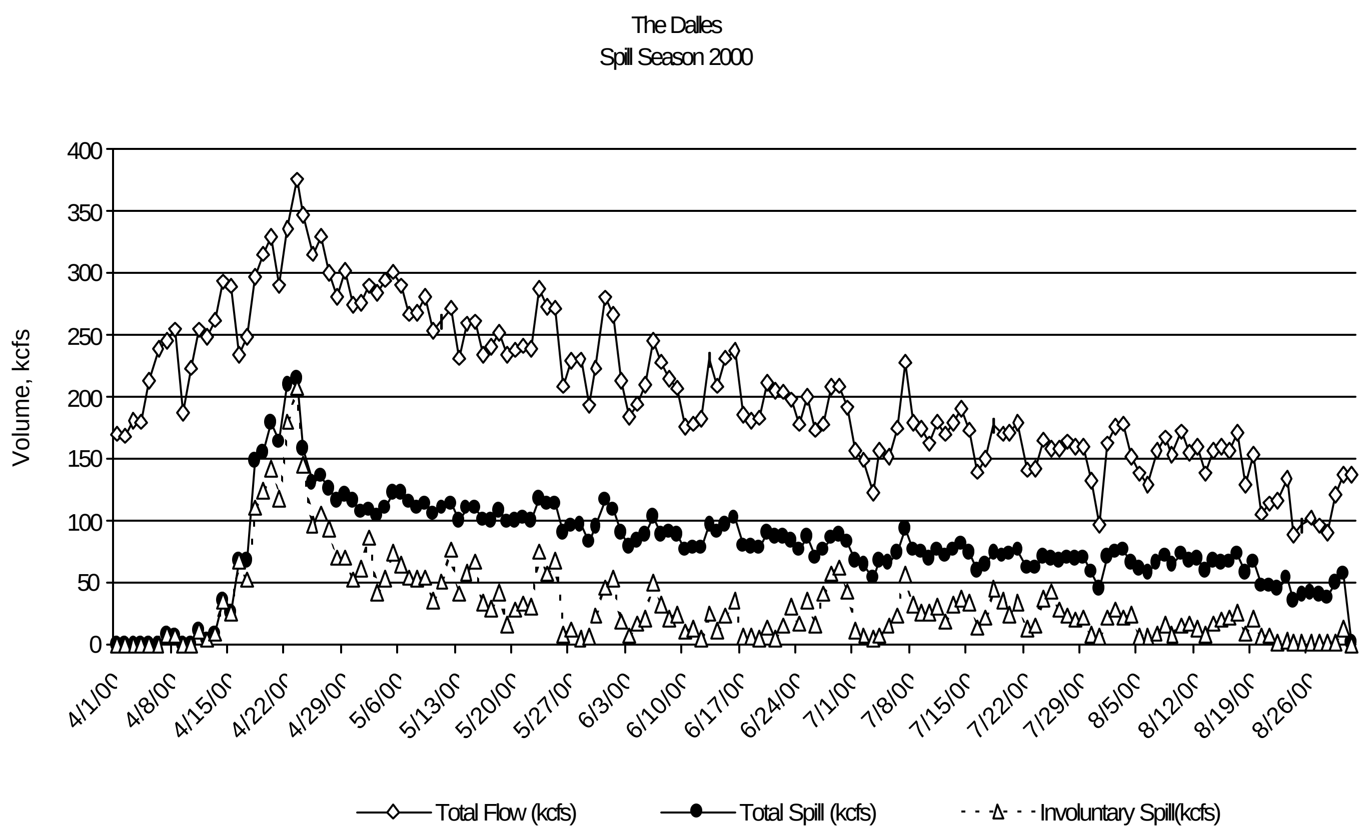


Figure 2 The Dalles – Involuntary Spill

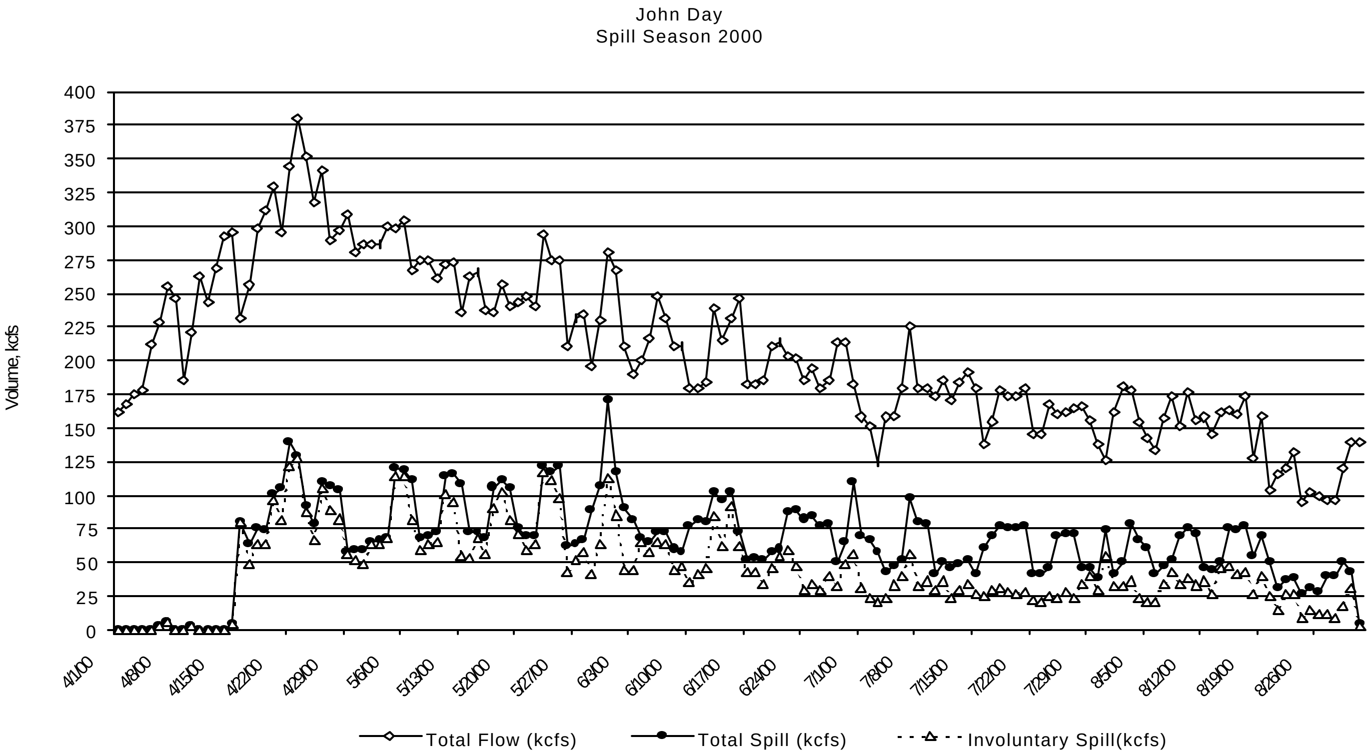


Figure 3 John Day – Involuntary Spill

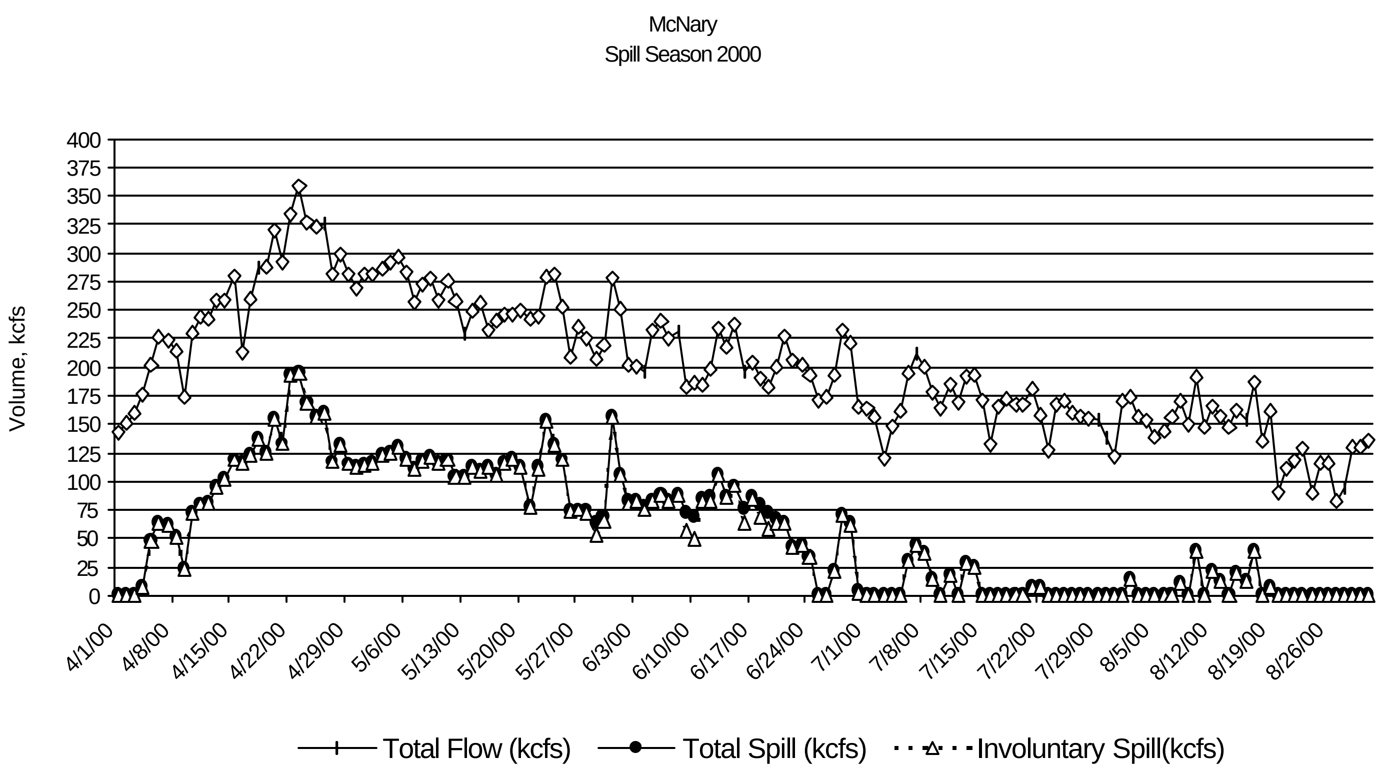


Figure 4 McNary – Involuntary Spill

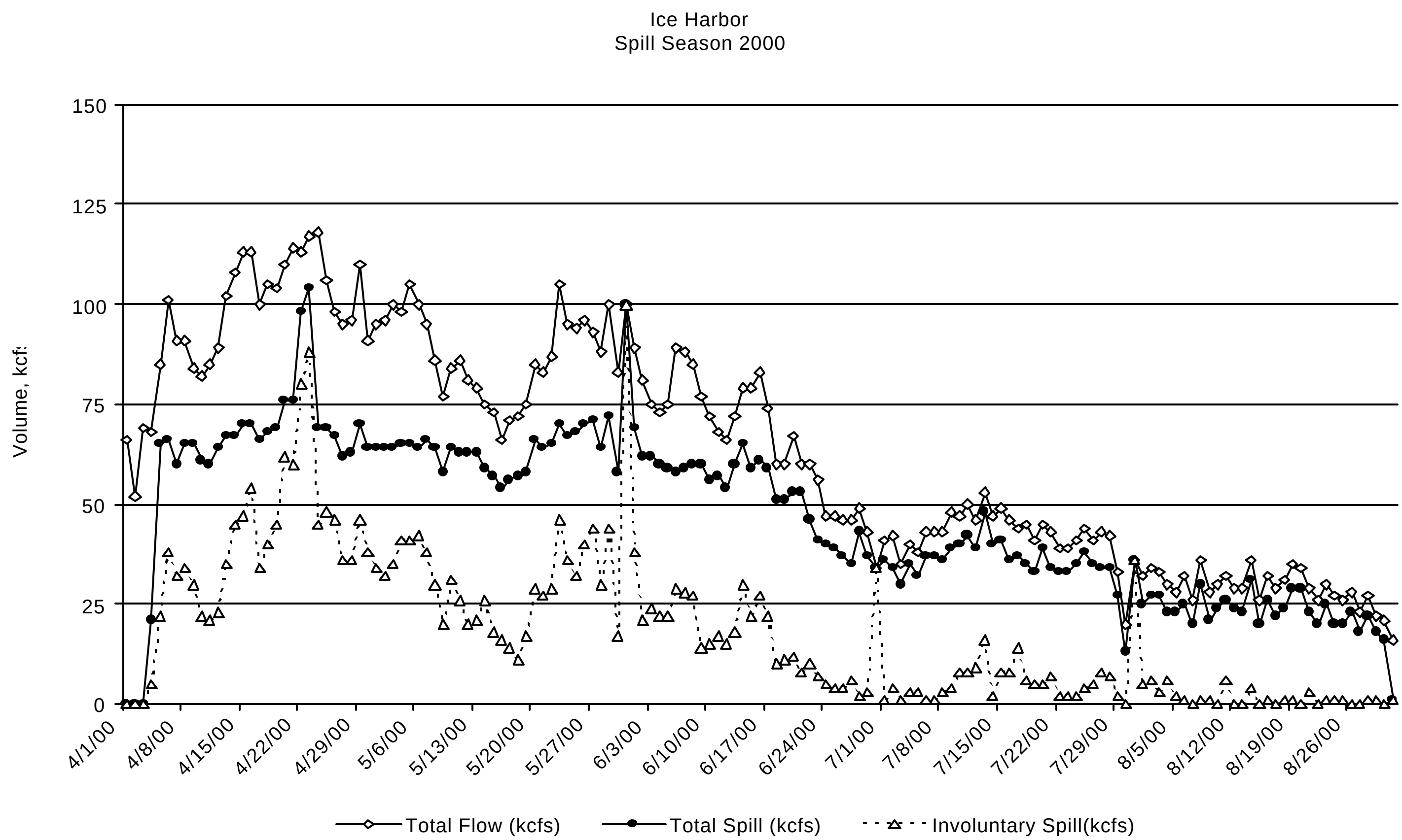


Figure 5 Ice Harbor – Involuntary Spill

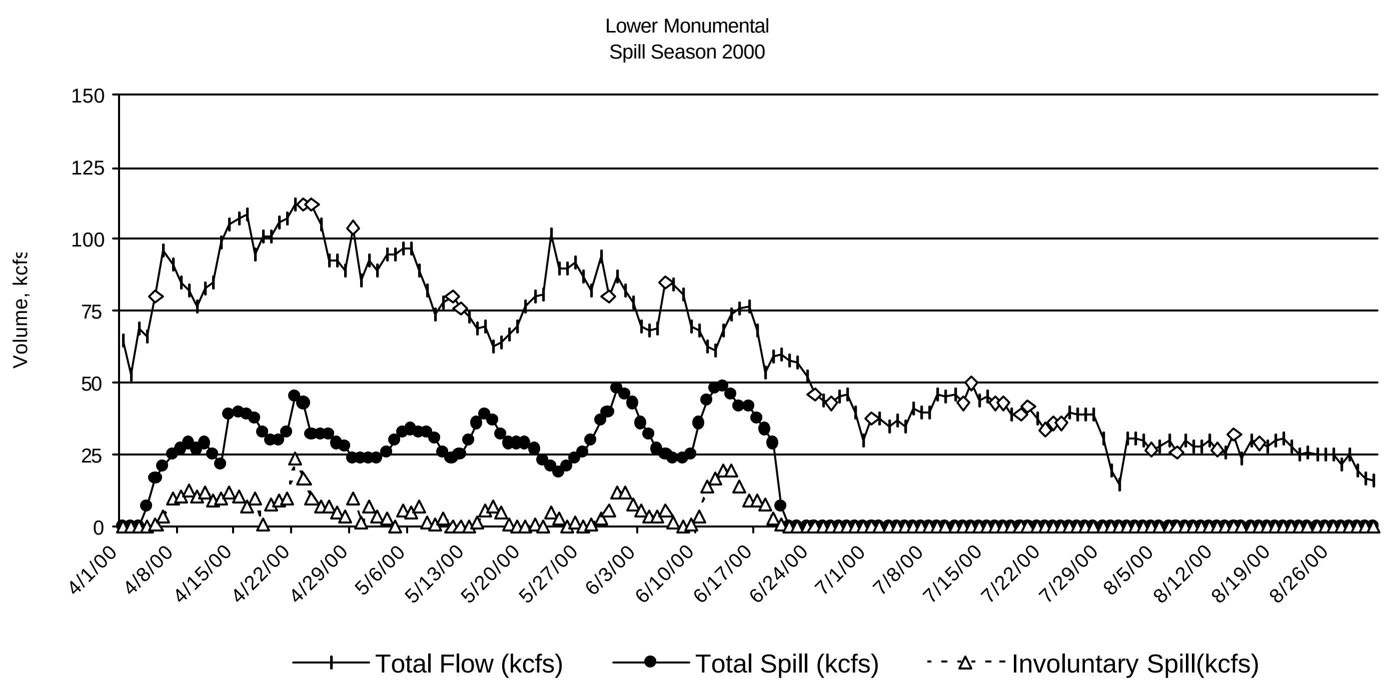


Figure 6 Lower Monumental – Involuntary Spill

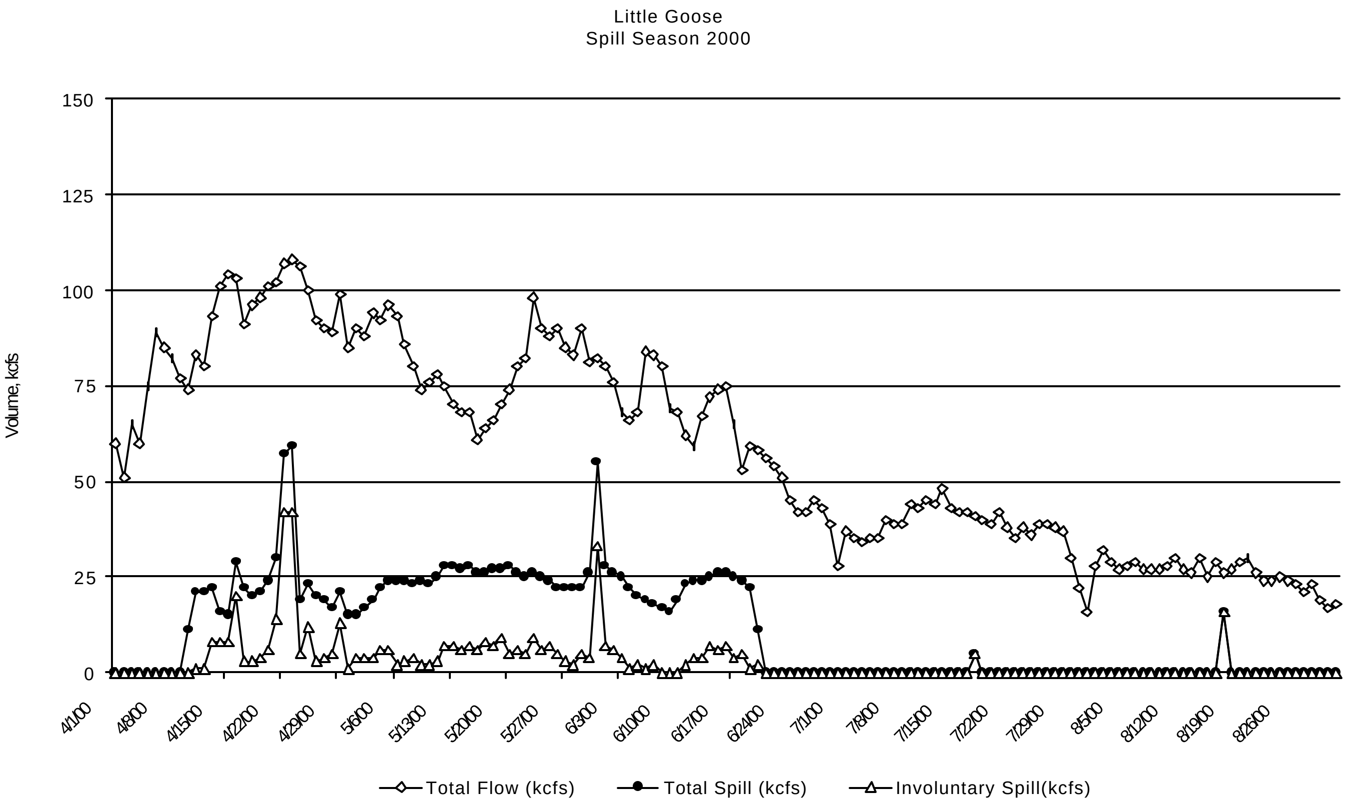


Figure 7 Little Goose – Involuntary Spill

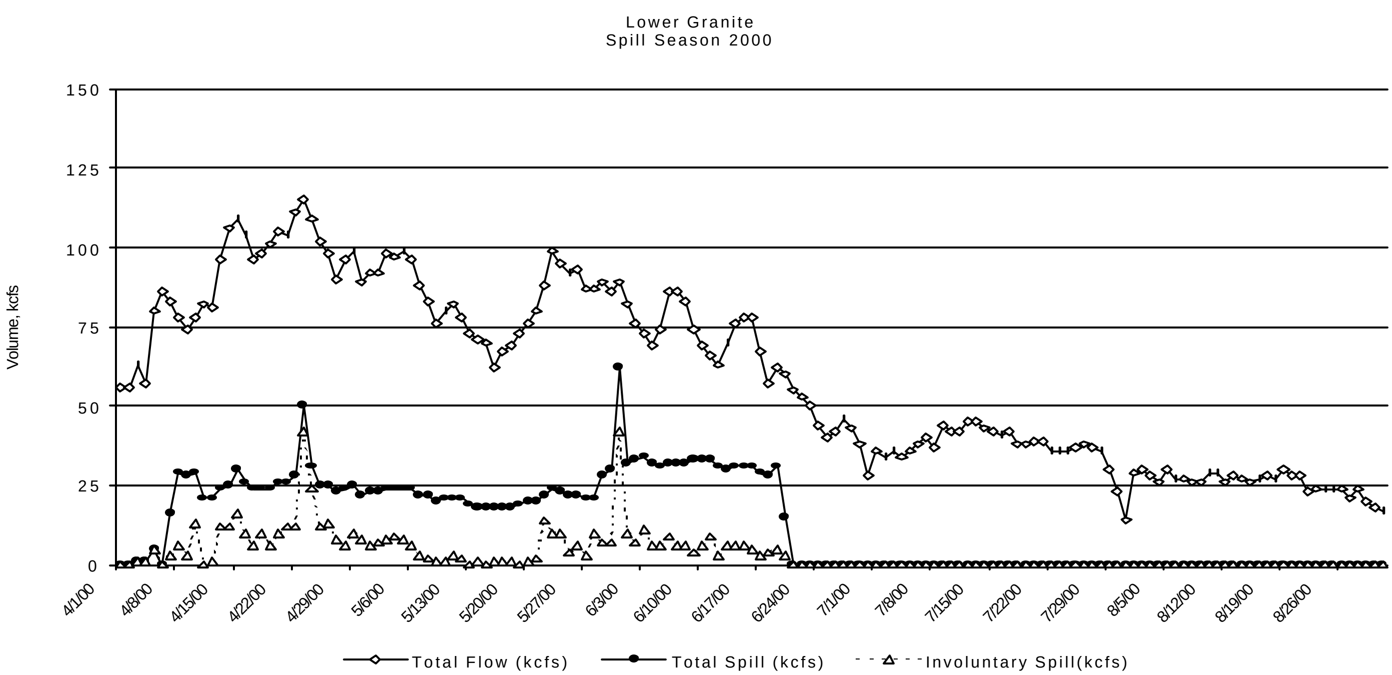
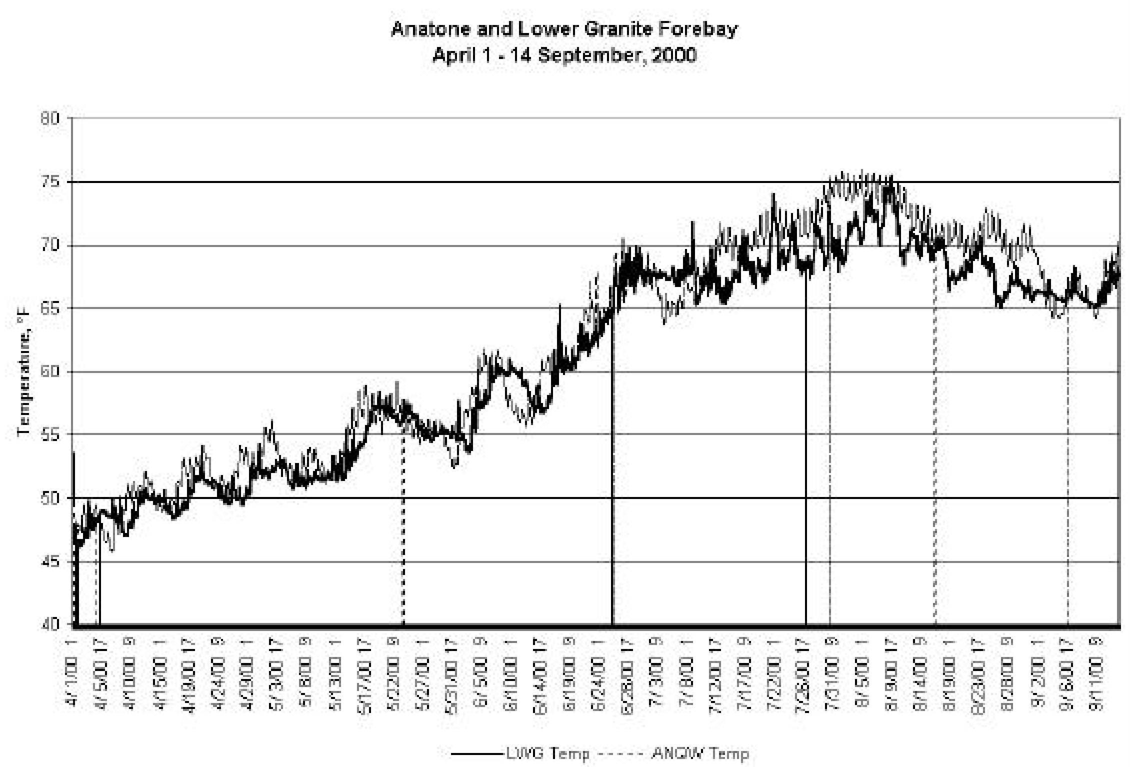


Figure 8 Lower Granite – Involuntary Spill

Dworshak Operations

During the 2000 spill season, cold-water releases from Dworshak reservoir were utilized to maintain cooler water temperatures in the Snake River. Temperature information from resistance thermal devices (RTDs), embedded in the face of the dam at the time of construction, along with an understanding of the overshot and undershot modes of operation of the selector gates were used to determine which elevation of water to release to attain the desired temperature. The temperature profile information was also used to estimate how long temperature control of release water could be maintained before the elevation of the pool was below the selector gate orifices or the warmer, surface layer mixing water was be exhausted.

The following graph contains the temperature data for Anatone and Lower Granite forebay. The reduction in temperature noted between the Anatone station and the Lower Granite forebay station are attributed to the Dworshak cool water releases.



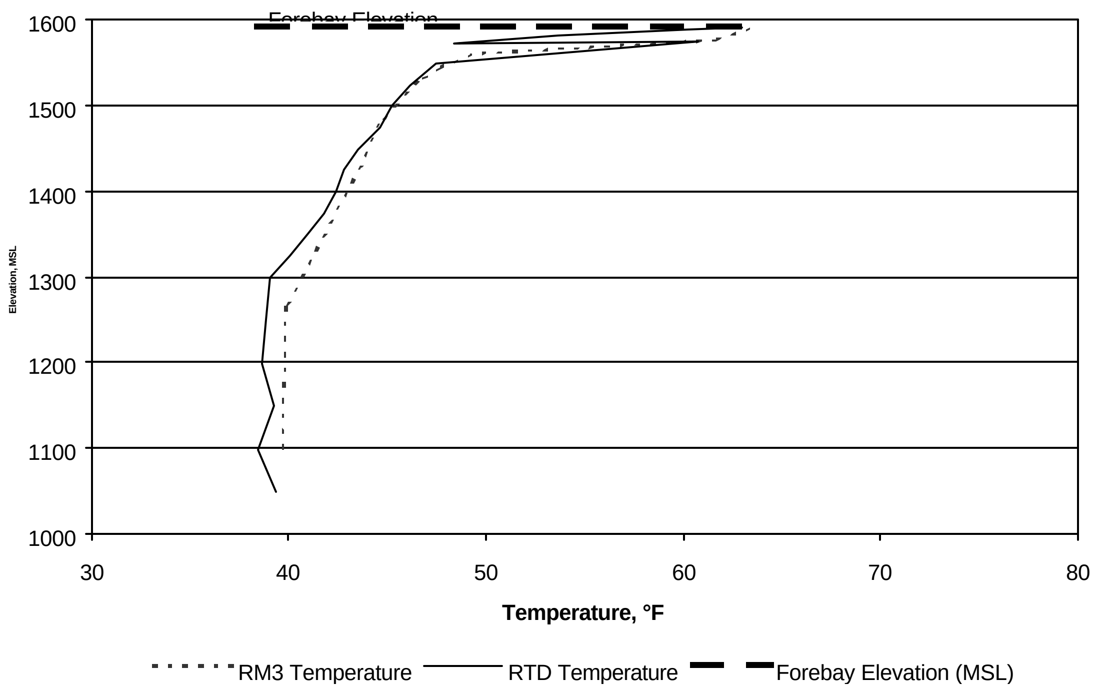
Since the RTDs were installed at the time of construction and are not routinely calibrated there was some concern as to their accuracy. The following 3 graphs include temperature data for 12 June, 17 July and 18 Aug 2000. These graphs contain the RTD data along with data collected at river mile 3 (RM3) of the north fork of the Clearwater River. RM3 is located in the Dworshak Dam forebay, approximately 0.5 miles from the face of Dworshak Dam.

Review of in-season decision-making and these temperature comparison graphs indicate that the accuracy of the RTDs is sufficient for determining forebay elevation releases.

Dworshak Temperature Profile Comparison

12Jun 2000

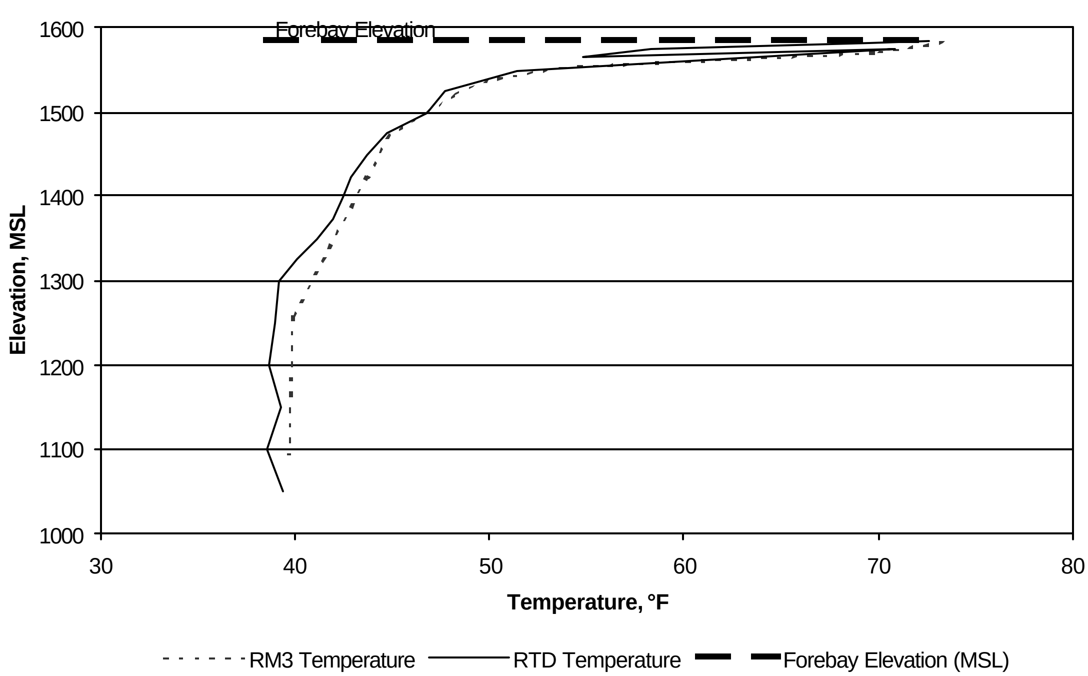
Resistance Thermal Devices (RTDs) and River Mile 3 (RM3)

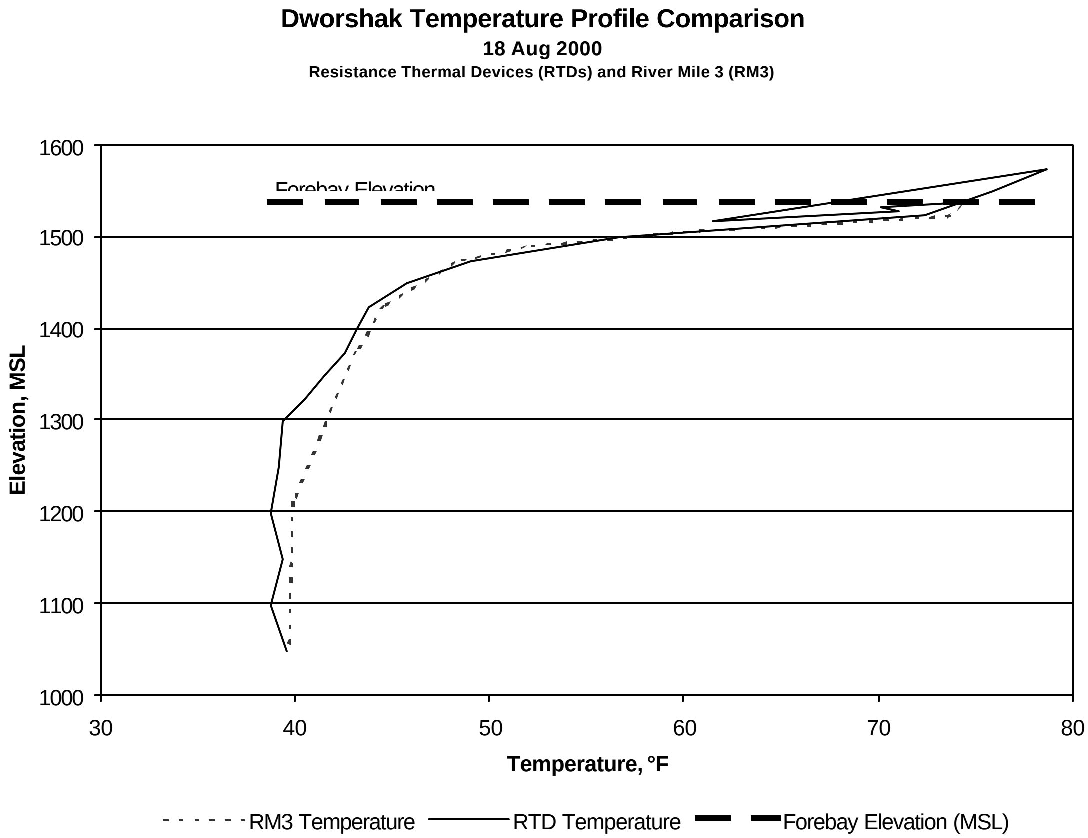


Dworshak Temperature Profile Comparison

17 Jul 2000

Resistance Thermal Devices (RTDs) and River Mile 3 (RM3)





Included next are a side view of the spillway and regulating outlet and side and front view schematics of the selector gates at Dworshak Dam.

Water is released during the spill season at Dworshak Dam for flow augmentation, temperature regulation and power generation. Augmentation water is passed through the powerhouse, over the spillway or through regulating outlets. Typically, above forebay elevation 1545 (the spillway crest), the spillway is used to pass water while maintaining a TDG level below the state standard of 110%. When more volume must be passed and the generation load is already met, water is passed using regulating outlets. Regulating outlets are at elevation 1353 resulting in cold water releases. The water temperature is monitored downstream at the Dworshak National Hatchery. A combination of spillway and/or regulating outlet spill and operating the units in over- or undershot mode is used to regulate the temperature releases.

Notes for the schematic:

- Flow is directed either over (overshot mode) or under (undershot mode) the selector gate, not variable at points in between
- In overshot mode, the top of the gate must be 50 feet below the surface of the forebay. Currently, due to physical limitations at the project, the lowest elevation for the top of the selector gate is 1475 in the overshot mode
- Water can also be released at elevation 1353 through a regulating outlet, bypassing the powerhouse and spillway.
- Water can be passed over the spillway only when the forebay elevation is above 1545.
- The Dworshak National Hatchery uses water directly from the Dworshak releases so releases must be within the range of tolerance for the hatchery

- The Dworshak power house contains 3 turbines: 1900cfs, 2100cfs and 5700cfs.
- Water release temperatures are attained by operating units in overshot or undershot mode to compensate for the spill (spillway or regulating outlet) temperature to achieve a mixture of water that is the desired temperature at the hatchery.
- Unit 2 entrains more air due to the design of the turbine. At low generation capacities this causes TDG levels to be higher than through unit 1.

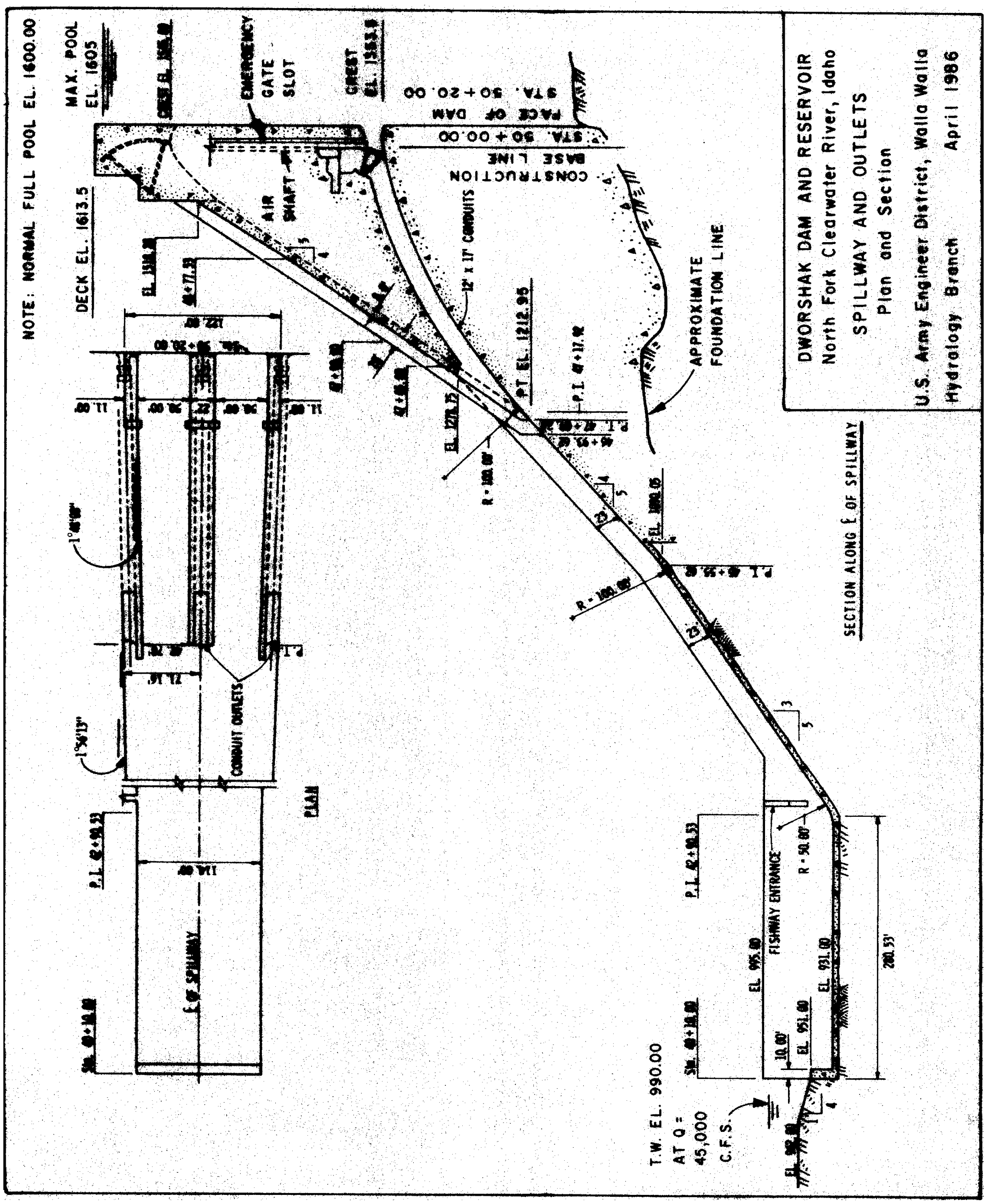


Figure 1. Spillway and Regulating Outlet, Dworshak Dam, Side View

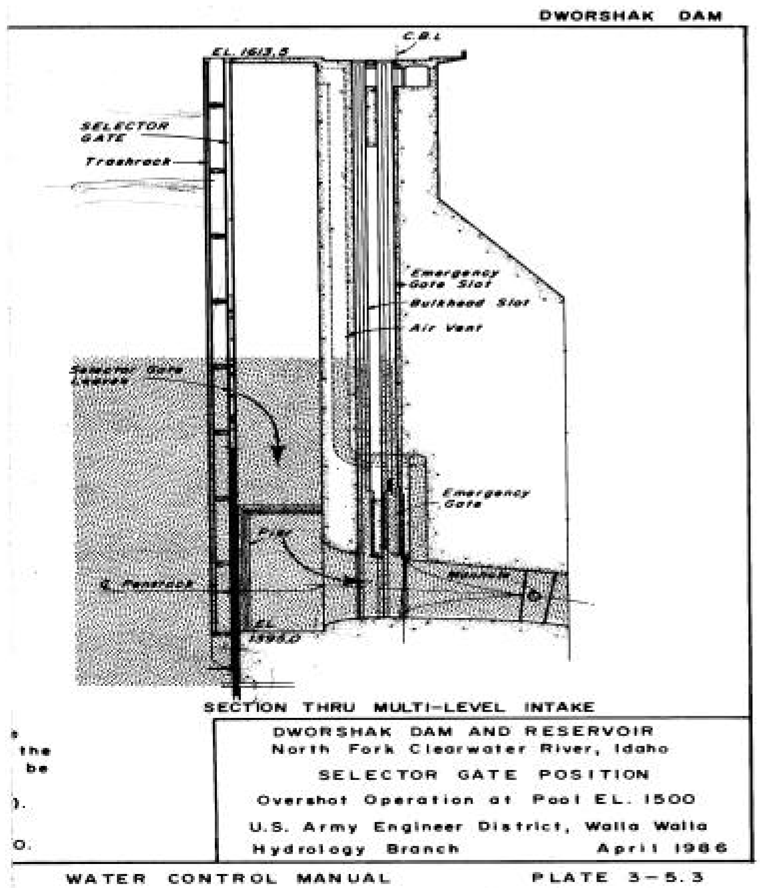


Figure 2. Selector Gate, Overshot Mode, Dworshak Dam, sideview

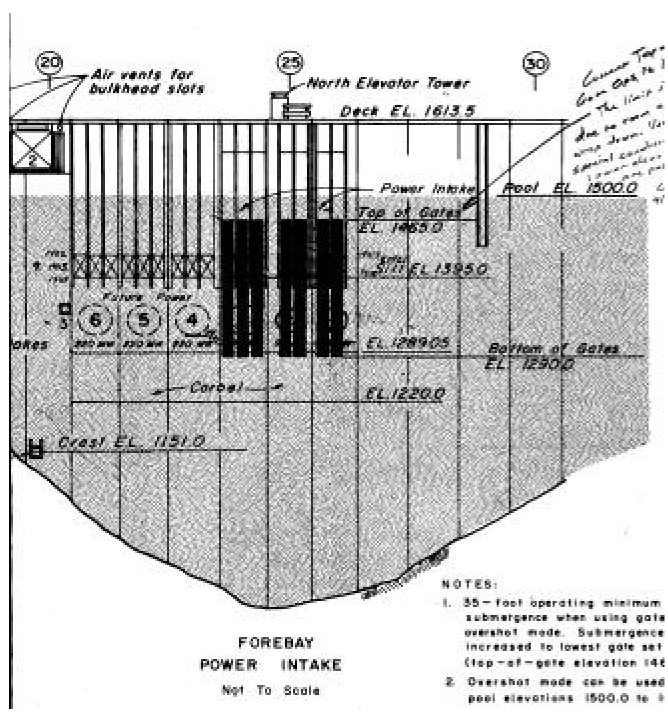


Figure 3. Selector Gate, Overshot Mode, Dworshak Dam, frontview

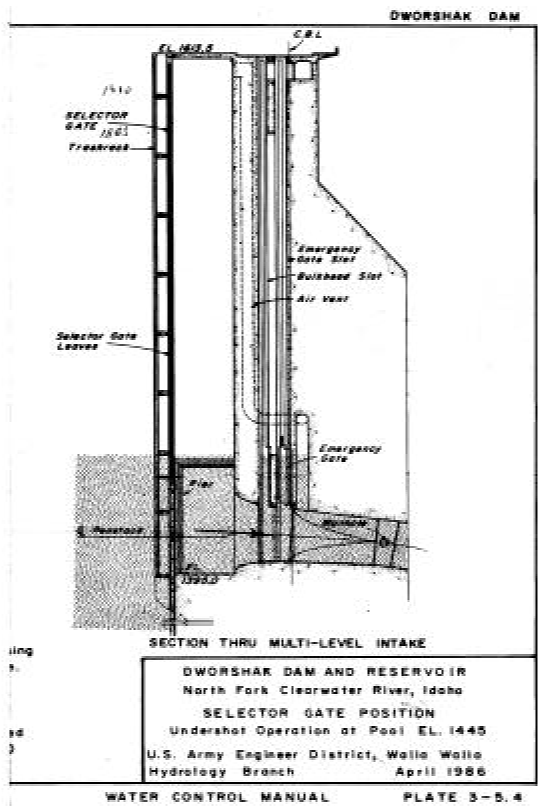


Figure 4. Selector Gate, Undershot Mode, Dworshak Dam, sideview

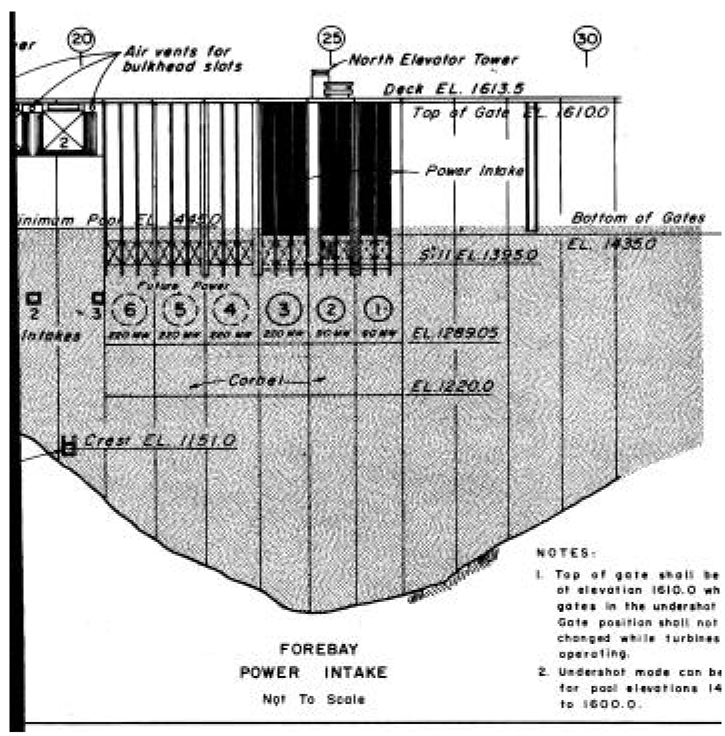


Figure 5. Selector Gate, Undershot Mode, Dworshak Dam, frontview

Appendix D
Section 1: TDG Min, Max, Number of hours and days over standards
Section 2: Temperature first and last day, day average and number of days over 68°F

Minimum and Maximum TDG % for Spill Season 2000

Station	Apr-00		May-00		Jun-00		Jul-00		Aug-00		Sep-00	
Chief Joseph Forebay (CHJ)	102.2	107.7	106.2	114.7	107.2	114.6	108.0	113.1	75.9	149.8	75.0	162.5
Number of hours over 115%		0		0		0		0		22		6
Number of days 12 hour avg over 115%		0		0		0		0		2		1
Chief Joseph Tailwater (CHQW)	100.8	132.4	105.1	120.0	105.2	114.4	105.9	114.3	99.7	112.8	102.0	109.7
Number of hours over 120%		12		0		0		0		0		0
Number of days 12 hour avg over 120%		0		0		0		0		0		0
Dworshak Tailwater (DWQI)	94.8	110.8	99.7	114.2	100.8	112.7	101.8	110.7	100.0	109.2	101.6	111.0
Number of hours over 110%		54		31		55		6		0		6
Peck (PEKI)	99.0	107.8	99.9	105.9	100.0	106.0	100.6	110.6	99.4	109.7	0.0	0.0
Number of hours over 110%		0		0		0		3		0		0
Lewiston (LEWI)	98.7	#######	99.7	106.8	98.7	106.5	98.8	109.6	99.4	108.1	0.0	0.0
Number of hours over 110%		1		0		0		0		0		0
Anatone (ANQW)	100.1	106.4	101.6	106.5	99.9	106.9	84.6	103.9	83.0	107.6	98.2	115.4
Number of hours over 115%		0		0		0		0		0		13
Number of days 12 hour avg over 115%		0		0		0		0		0		0

Minimum and Maximum TDG % for Spill Season 2000

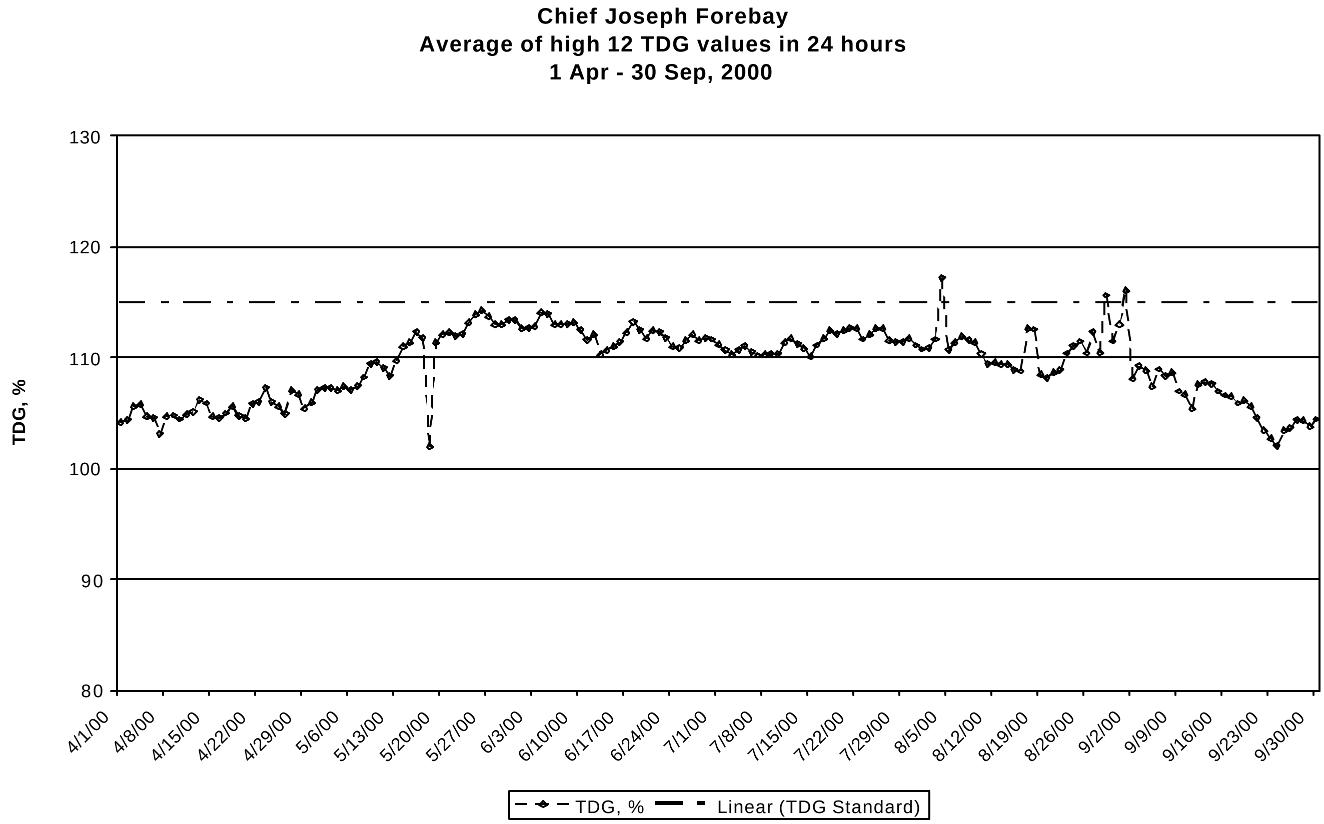
Station	Apr-00 Min	Apr-00 Max	May-00 Min	May-00 Max	Jun-00 Min	Jun-00 Max	Jul-00 Min	Jul-00 Max	Aug-00 Min	Aug-00 Max	Sep-00 Min	Sep-00 Max
Lower Granite Forebay (LWG)	100.6	108.4	101.3	109.9	99.6	114.8	100.0	117.6	100.7	116.8	96.1	111.1
Number of hours over 115%		0		0		0		7		15		0
Number of days 12 hour avg over 115%		0		0		0		1		1		0
Lower Granite Tailwater (LGNW)	100.4	122.2	103.8	120.7	99.9	122.0	99.2	105.6	99.3	105.2	95.6	103.9
Number of hours over 120%		20		2		31		0		0		0
Number of days 12 hour avg over 120%		2		0		2		0		0		0
Little Goose Forebay (LGS)	100.9	116.3	103.1	113.9	102.1	117.2	96.9	112.0	96.6	107.9	92.7	116.7
Number of hours over 115%		8		0		8		0		0		3
Number of days 12 hour avg over 115%		1		0		1		0		0		0
Little Goose Tailwater (LGSW)	100.5	128.1	103.8	121.0	101.6	121.1	96.6	117.2	96.6	116.4	93.5	99.7
Number of hours over 120%		23		91		32		0		0		0
Number of days 12 hour avg over 120%		2		5		2		0		0		0
Lower Monumental Forebay (LMN)	100.4	120.6	105.4	120.0	104.2	120.0	98.1	111.9	97.6	113.5	96.3	114.8
Number of hours over 115%		113		136		111		0		0		0
Number of days 12 hour avg over 115%		8		12		8		0		0		0
Lower Monumental Tailwater (LMNW	99.5	126.0	111.7	120.5	103.8	121.8	97.2	105.4	96.2	103.1	71.4	102.5
Number of hours over 120%		109		4		41		0		0		0
Number of days 12 hour avg over 120%		9		0		3		0		0		0
Ice Harbor Forebay (IHR)	102.0	119.4	107.7	120.5	107.8	122.7	95.9	110.3	95.8	106.2	95.6	110.6
Number of hours over 115%		218		261		215		0		0		0
Number of days 12 hour avg over 115%		9		15		10		0		0		0
Ice Harbor Tailwater (IDSW)	101.7	124.3	109.2	119.8	106.8	119.1	102.7	113.9	100.7	112.9	96.9	105.8
Number of hours over 120%		71		0		0		0		0		0
Number of days 12 hour avg over 120%		4		0		0		0		0		0
Pasco (PAQW)	100.7	118.5	102.9	116.2	103.3	113.8	99.6	114.3	99.7	113.6	98.3	104.9
Number of hours over 115%		45		20		0		0		0		0
Number of days 12 hour avg over 115%		3		3		0		0		0		0

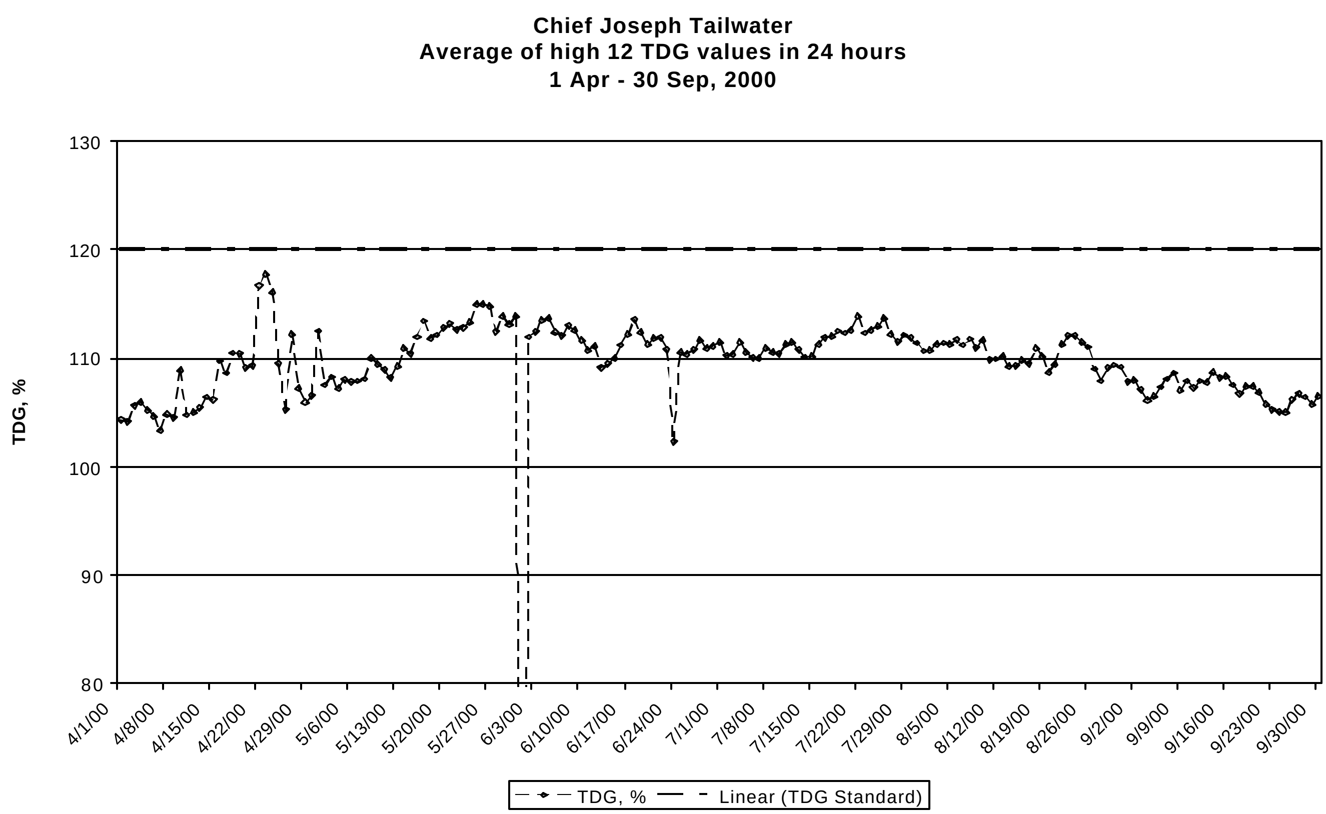
Minimum and Maximum TDG % for Spill Season 2000

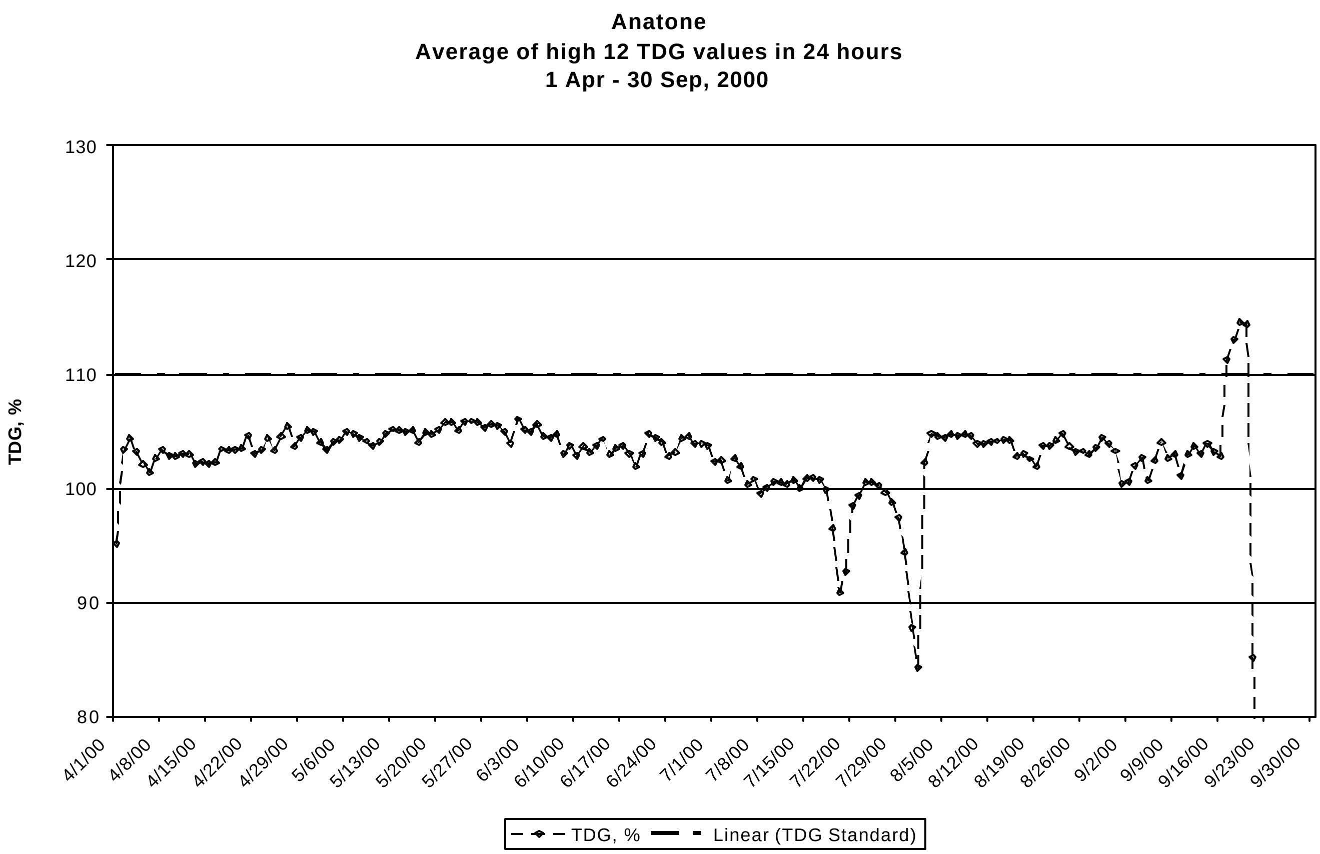
Station	Apr-00 Min	Apr-00 Max	May-00 Min	May-00 Max	Jun-00 Min	Jun-00 Max	Jul-00 Min	Jul-00 Max	Aug-00 Min	Aug-00 Max	Sep-00 Min	Sep-00 Max
McNary Oregon Forebay (MCQO)	101.0	118.2	105.4	120.1	104.4	119.6	102.4	118.2	100.8	116.5	97.0	111.3
Number of hours over 115%		27		157		48		62		22		0
Number of days 12 hour avg over 115%		1		12		4		4		1		0
McNary Washington Forebay (MCQV	102.7	117.5	104.4	120.3	104.0	116.4	103.8	113.4	102.6	112.6	97.2	106.3
Number of hours over 115%		36		161		16		0		0		0
Number of days 12 hour avg over 115%		3		10		1		0		0		0
McNary Tailwater (MCPW)	103.4	127.3	107.5	121.2	104.6	121.4	102.6	114.4	102.1	116.8	97.8	103.5
Number of hours over 120%		204		34		56		0		0		0
Number of days 12 hour avg over 120%		10		3		4		0		0		0
John Day Forebay (JDA)	100.1	116.0	103.3	116.9	102.9	114.2	100.1	107.2	97.1	107.3	97.8	104.8
Number of hours over 115%		11		7		0		0		0		0
Number of days 12 hour avg over 115%		1		0		0		0		0		0
John Day Tailwater JHAW)	101.7	123.3	107.4	121.1	105.9	123.7	1.8	118.9	100.9	118.8	98.3	107.1
Number of hours over 120%		178		6		2		0		0		0
Number of days 12 hour avg over 120%		12		0		0		0		0		0
The Dalles Forebay (TDA)	100.9	145.7	104.3	116.2	103.0	117.5	100.8	113.2	99.7	112.5	98.0	107.3
Number of hours over 115%		41		28		33		0		0		0
Number of days 12 hour avg over 115%		3		0		2		0		0		0
The Dalles Tailwater (TDDO)	101.2	119.4	113.0	121.7	111.2	121.4	109.1	117.8	107.5	115.6	97.9	110.3
Number of hours over 120%		0		68		9		0		0		0
Number of days 12 hour avg over 120%		0		4		1		0		0		0
Bonneville Forebay (BON)	100.3	118.2	103.2	117.4	105.3	116.8	103.5	111.6	101.0	110.0	97.4	105.3
Number of hours over 115%		115		97		21		0		0		0
Number of days 12 hour avg over 115%		6		6		2		0		0		0
Skamania (SKAW)	100.5	123.2	109.5	120.1	110.1	122.1	111.0	121.4	107.0	122.2	91.6	114.0
Number of hours over 120%		12		1		82		94		25		0
Number of days 12 hour avg over 120%		1		0		5		5		1		0
Warrendale (WRNO)	101.9	123.0	109.6	119.5	109.6	122.4	109.3	124.2	108.2	119.4	98.2	113.1
Number of hours over 120%		32		0		36		30		0		0
Number of days 12 hour avg over 120%		3		0		2		1		0		0
Camas/Washougal (CWMW)	101.4	122.2	109.0	120.3	107.5	130.5	107.9	130.9	106.6	118.0	98.6	112.7
Number of hours over 115%		227		335		246		189		68		0
Number of days 12 hour avg over 115%		12		15		16		11		4		0

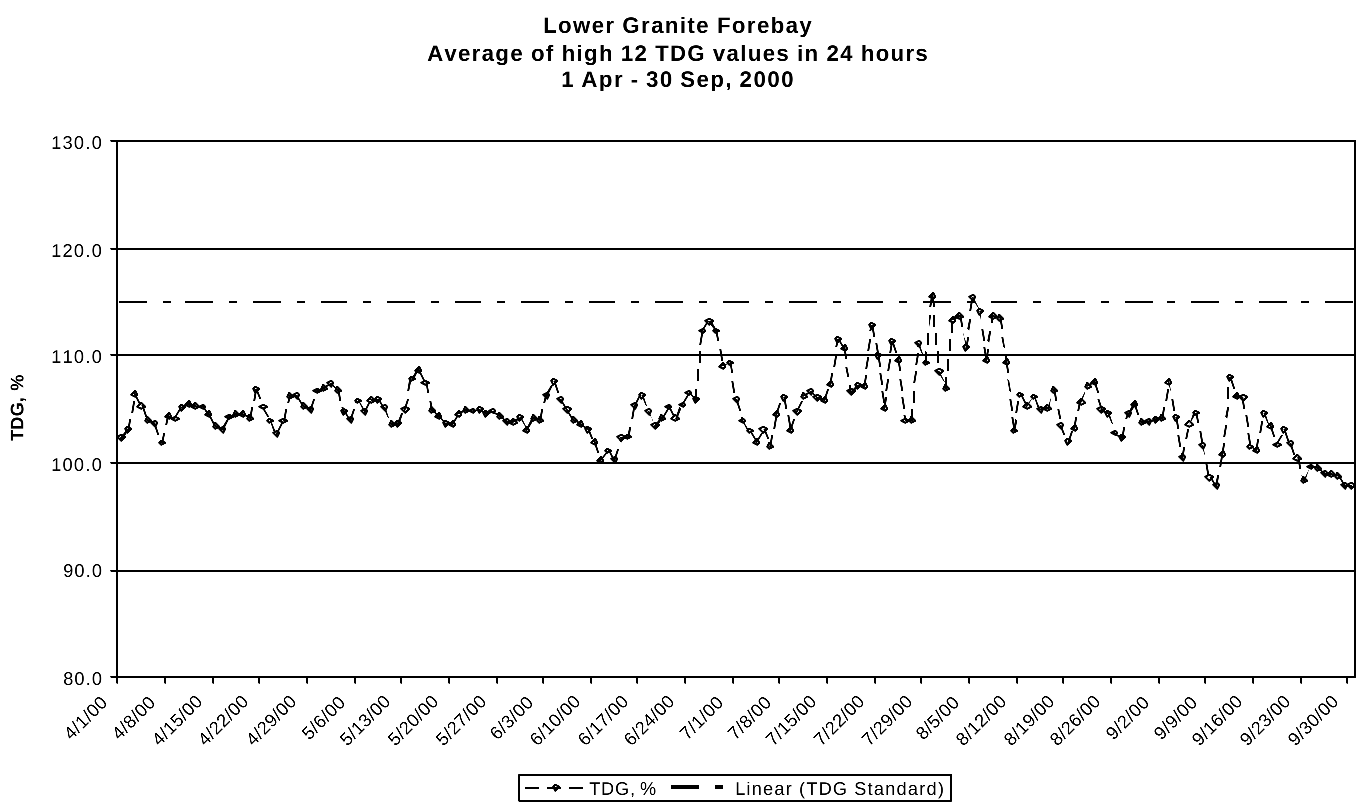
Locations	Period of Data	Hourly Data			24 Hour Average Data		
		First hour Over 68°F	Last hour over 68°F	Number of Days with hourly data	Date 1st 24H Ave Over 68°F	Date Last 24H Ave Over 68°F	Num of Days of 24H Ave Over 68°F
CHJ	Spill Season	08/23/00	08/23/00	1	N/A	N/A	0
CHQW	Spill Season	N/A	N/A	0	N/A	N/A	0
DWQI	Spill Season	N/A	N/A	0	N/A	N/A	0
PEKI	Spill Season	09/10/00	09/10/00	1	N/A	N/A	0
LEWI	Spill Season	09/04/00	09/06/00	3	N/A	N/A	0
ANQW	Spill Season	06/30/00	09/27/00	77	06/29/00	09/19/00	63
LWG	Spill Season	07/01/00	09/28/00	64	06/28/00	09/20/00	42
LGNW	Spill Season	07/30/00	07/30/00	1	N/A	N/A	0
LGS	Spill Season	06/29/00	09/21/00	51	07/08/00	08/23/00	34
LGSW	Spill Season	07/25/00	08/23/00	30	07/21/00	08/15/00	22
LMN	Spill Season	07/15/00	09/21/00	57	07/11/00	08/29/00	47
LMNW	Spill Season	07/15/00	09/24/00	48	07/23/00	08/21/00	30
IHR	Spill Season	07/15/00	09/27/00	61	07/11/00	09/03/00	55
IDSW	Spill Season	07/16/00	09/11/00	58	07/13/00	09/04/00	54
PAQW	Spill Season	08/04/00	09/07/00	20	07/30/00	08/26/00	13
MCQW	Spill Season	07/12/00	09/28/00	58	07/20/00	08/31/00	42
MCQO	Spill Season	06/20/00	09/28/00	80	07/10/00	09/18/00	50
MCPW	Spill Season	07/25/00	09/08/00	45	07/24/00	08/31/00	39
JDA	Spill Season	06/29/00	09/21/00	60	07/16/00	09/14/00	51
JHAW	Spill Season	07/25/00	09/15/00	53	07/21/00	09/08/00	50
TDA	Spill Season	07/25/00	09/14/00	51	07/21/00	09/02/00	44
TDDO	Spill Season	07/25/00	09/14/00	50	07/20/00	09/04/00	46
BON	Spill Season	07/25/00	09/07/00	41	07/21/00	07/21/00	37
SKAW	Spill Season	07/25/00	09/08/00	45	07/21/00	01/00/00	42
WRNO	Spill Season	07/25/00	09/21/00	47	07/21/00	08/30/00	40
CWMW	Spill Season	07/02/00	09/24/00	59	07/20/00	09/24/00	45

Appendix E
TDG data graphs
Average of 12 high values in 24 hours

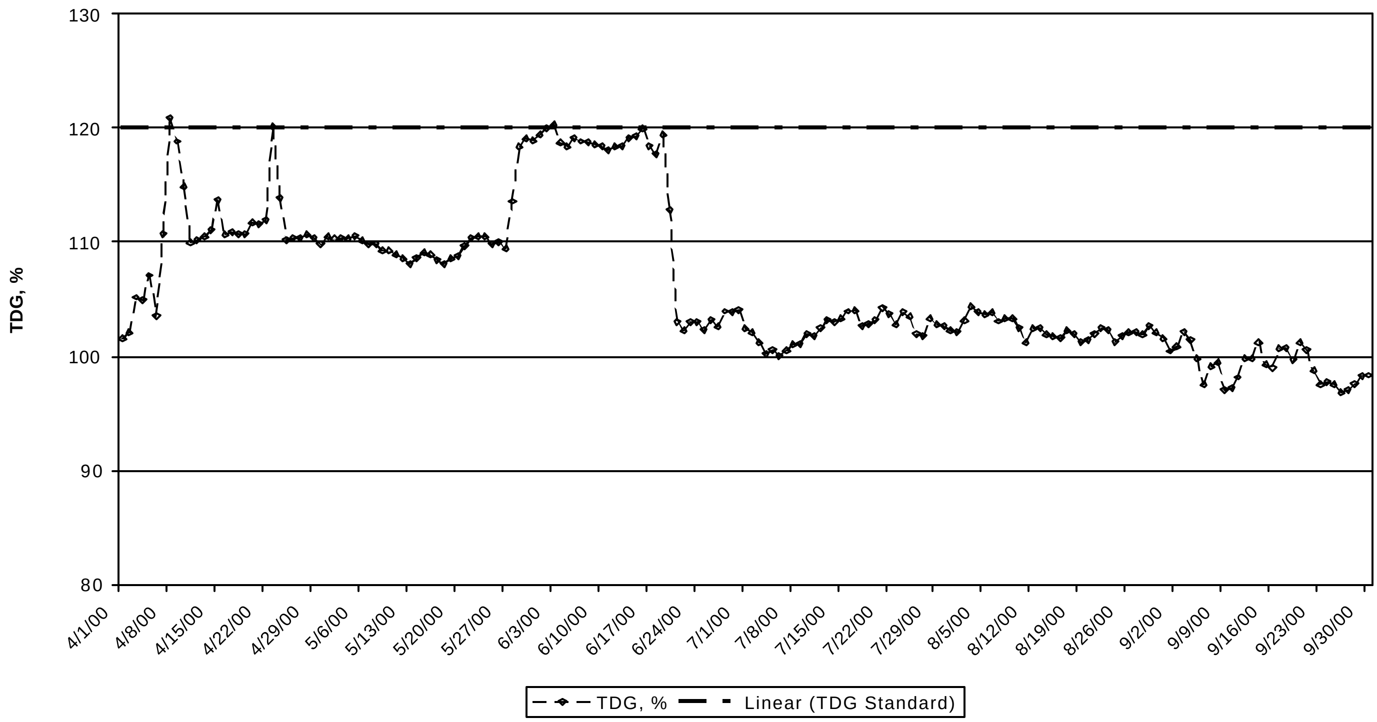

Chief Joseph Forebay
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000
TDG, %
130
120
110
100
90
80
4/1/00
4/8/00
4/15/00
4/22/00
4/29/00
5/6/00
5/13/00
5/20/00
5/27/00
6/3/00
6/10/00
6/17/00
6/24/00
7/1/00
7/8/00
7/15/00
7/22/00
7/29/00
8/5/00
8/12/00
8/19/00
8/26/00
9/2/00
9/9/00
9/16/00
9/23/00
9/30/00
TDG, %
Linear (TDG Standard)


Chief Joseph Tailwater
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000
TDG, %
130
120
110
100
90
80
4/1/00
4/8/00
4/15/00
4/22/00
4/29/00
5/6/00
5/13/00
5/20/00
5/27/00
6/3/00
6/10/00
6/17/00
6/24/00
7/1/00
7/8/00
7/15/00
7/22/00
7/29/00
8/5/00
8/12/00
8/19/00
8/26/00
9/2/00
9/9/00
9/16/00
9/23/00
9/30/00
TDG, %
Linear (TDG Standard)

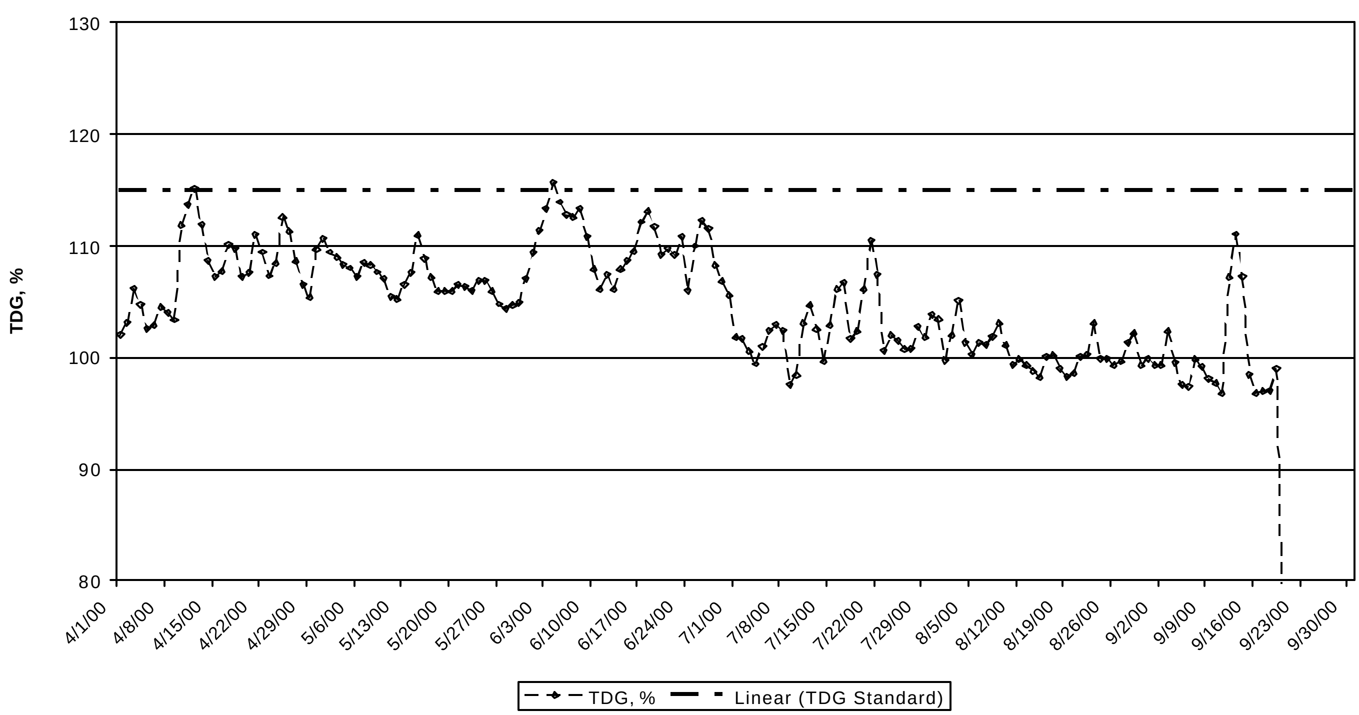

Anatone
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000
TDG, %
130
120
110
100
90
80
4/1/00
4/8/00
4/15/00
4/22/00
4/29/00
5/6/00
5/13/00
5/20/00
5/27/00
6/3/00
6/10/00
6/17/00
6/24/00
7/1/00
7/8/00
7/15/00
7/22/00
7/29/00
8/5/00
8/12/00
8/19/00
8/26/00
9/2/00
9/9/00
9/16/00
9/23/00
9/30/00
TDG, %
Linear (TDG Standard)


Lower Granite Forebay
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000
TDG, %
130.0
120.0
110.0
100.0
90.0
80.0
4/1/00
4/8/00
4/15/00
4/22/00
4/29/00
5/6/00
5/13/00
5/20/00
5/27/00
6/3/00
6/10/00
6/17/00
6/24/00
7/1/00
7/8/00
7/15/00
7/22/00
7/29/00
8/5/00
8/12/00
8/19/00
8/26/00
9/2/00
9/9/00
9/16/00
9/23/00
9/30/00
TDG, %
Linear (TDG Standard)

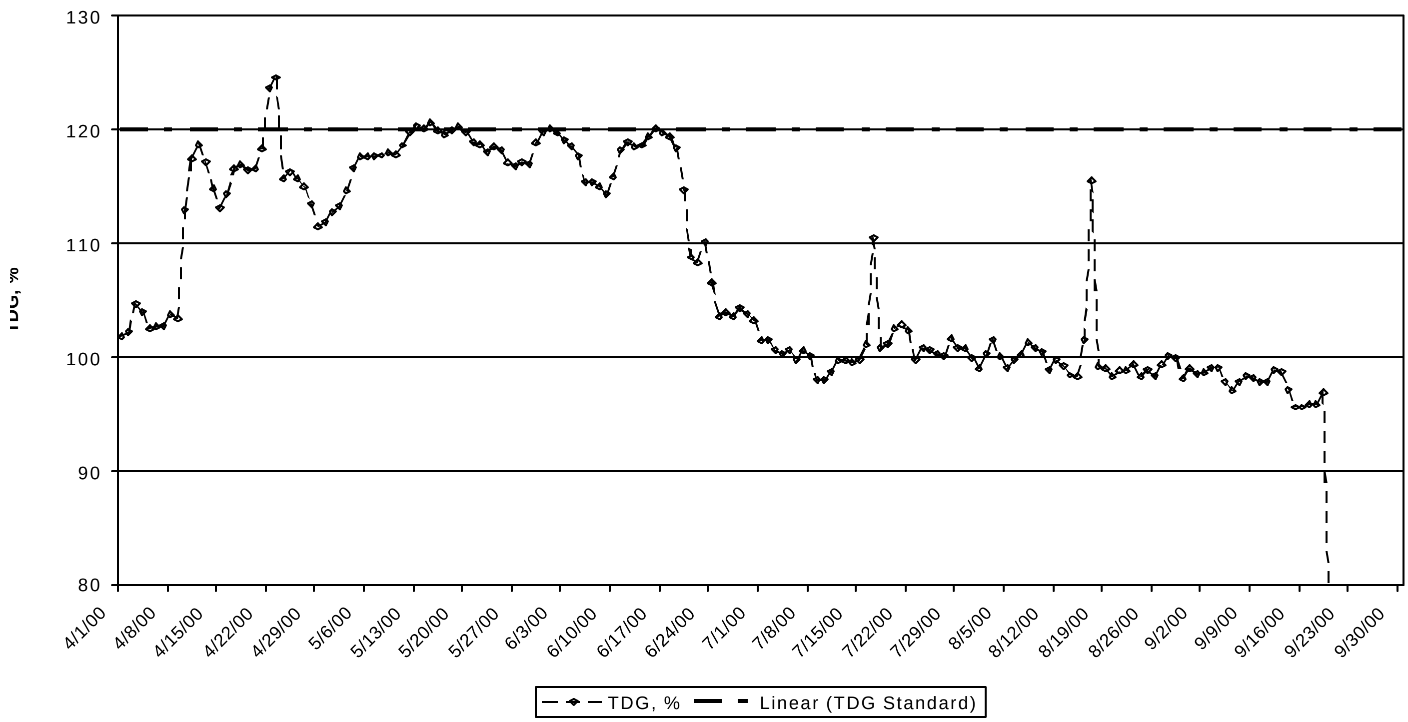
Lower Granite Tailwater
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000



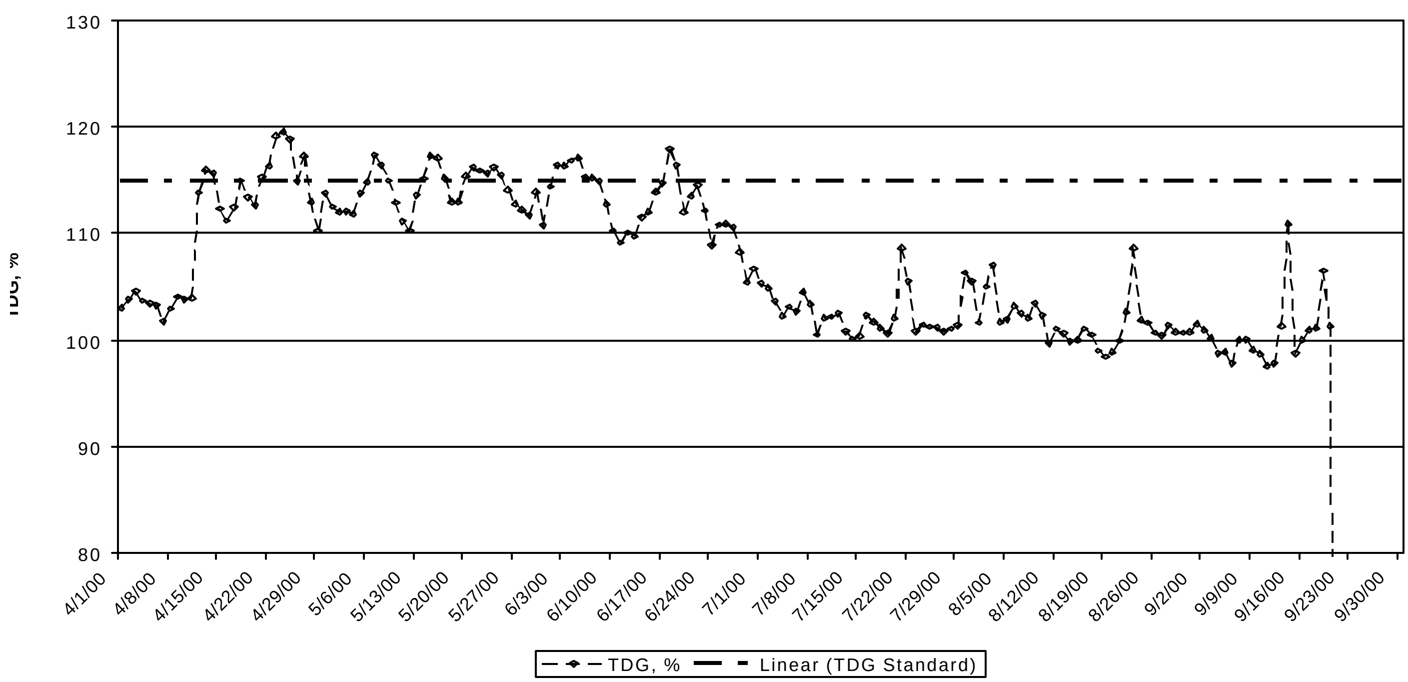
Little Goose Forebay
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000



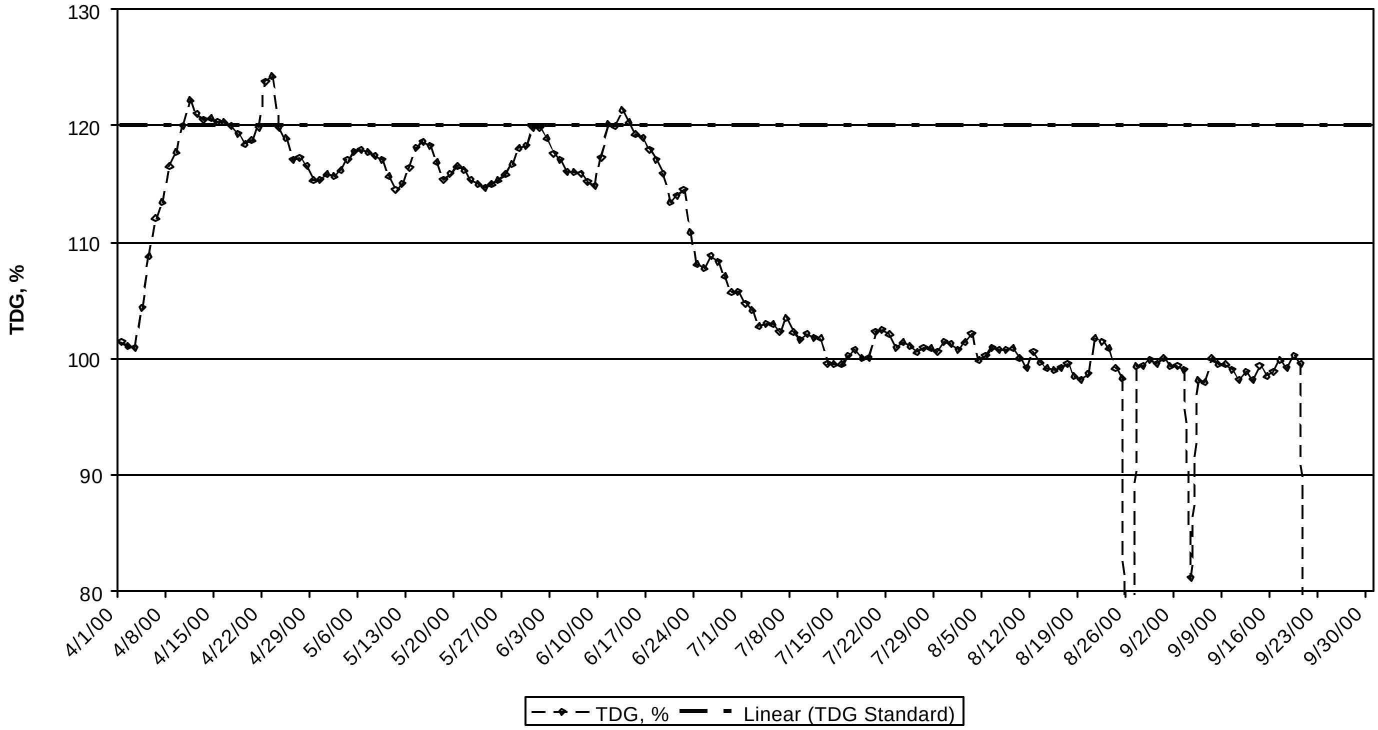
Little Goose Tailwater
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000



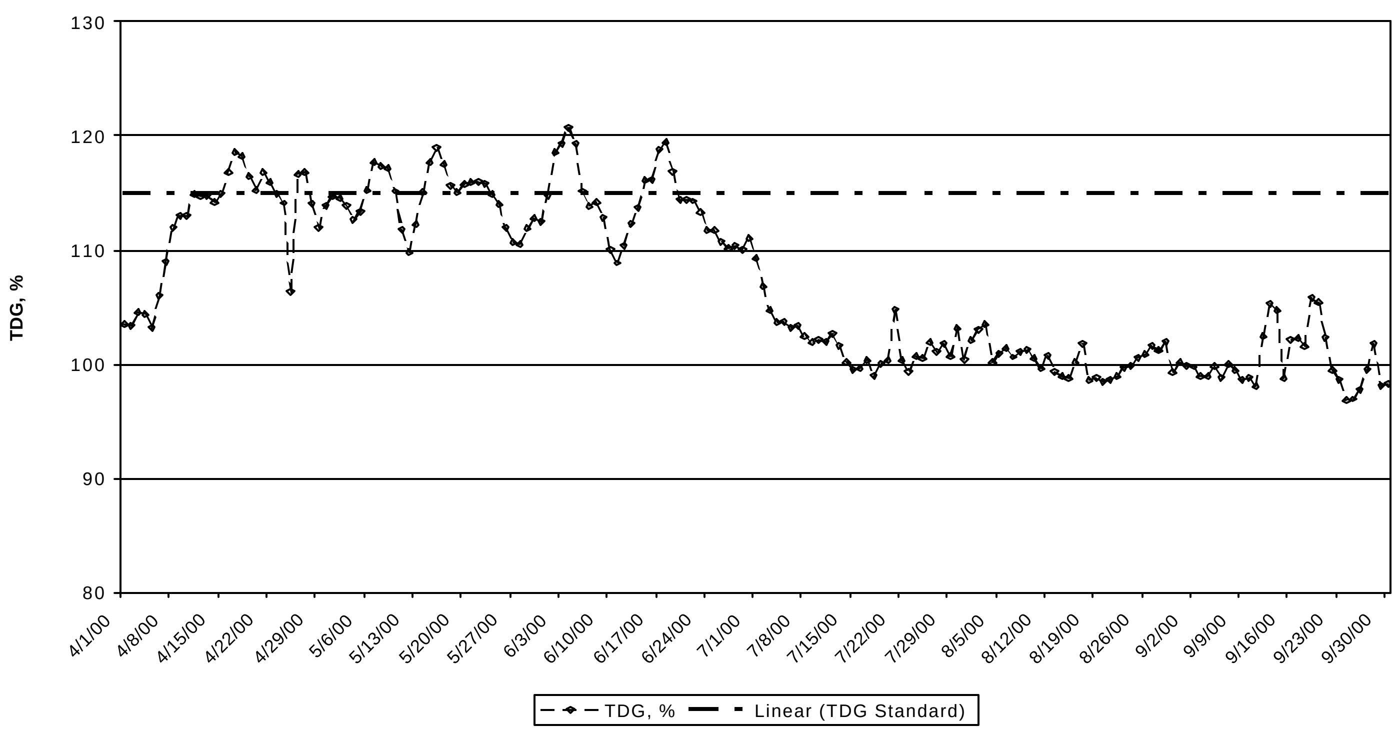
Lower Monumental Forebay
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000

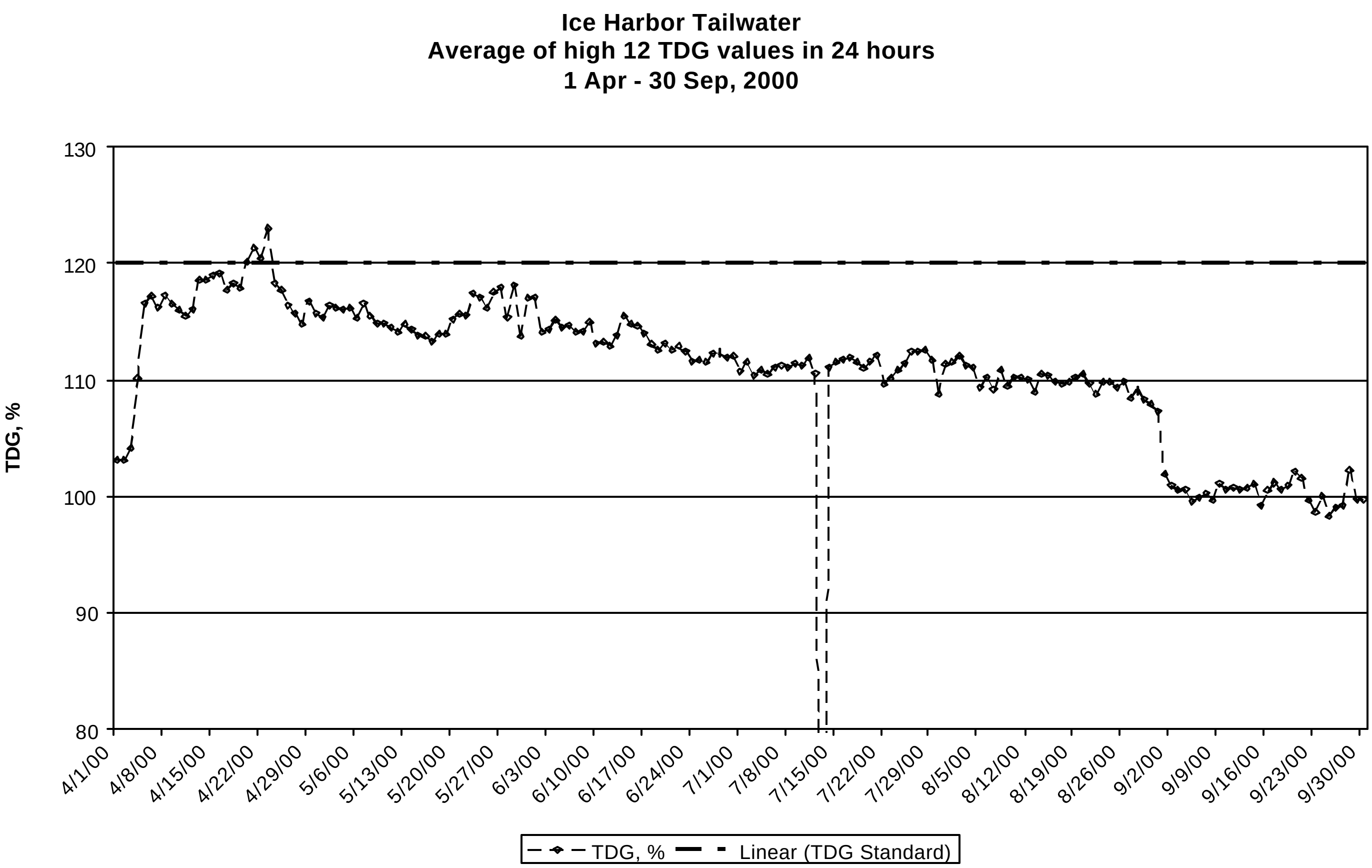


Lower Monumental Tailwater
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000

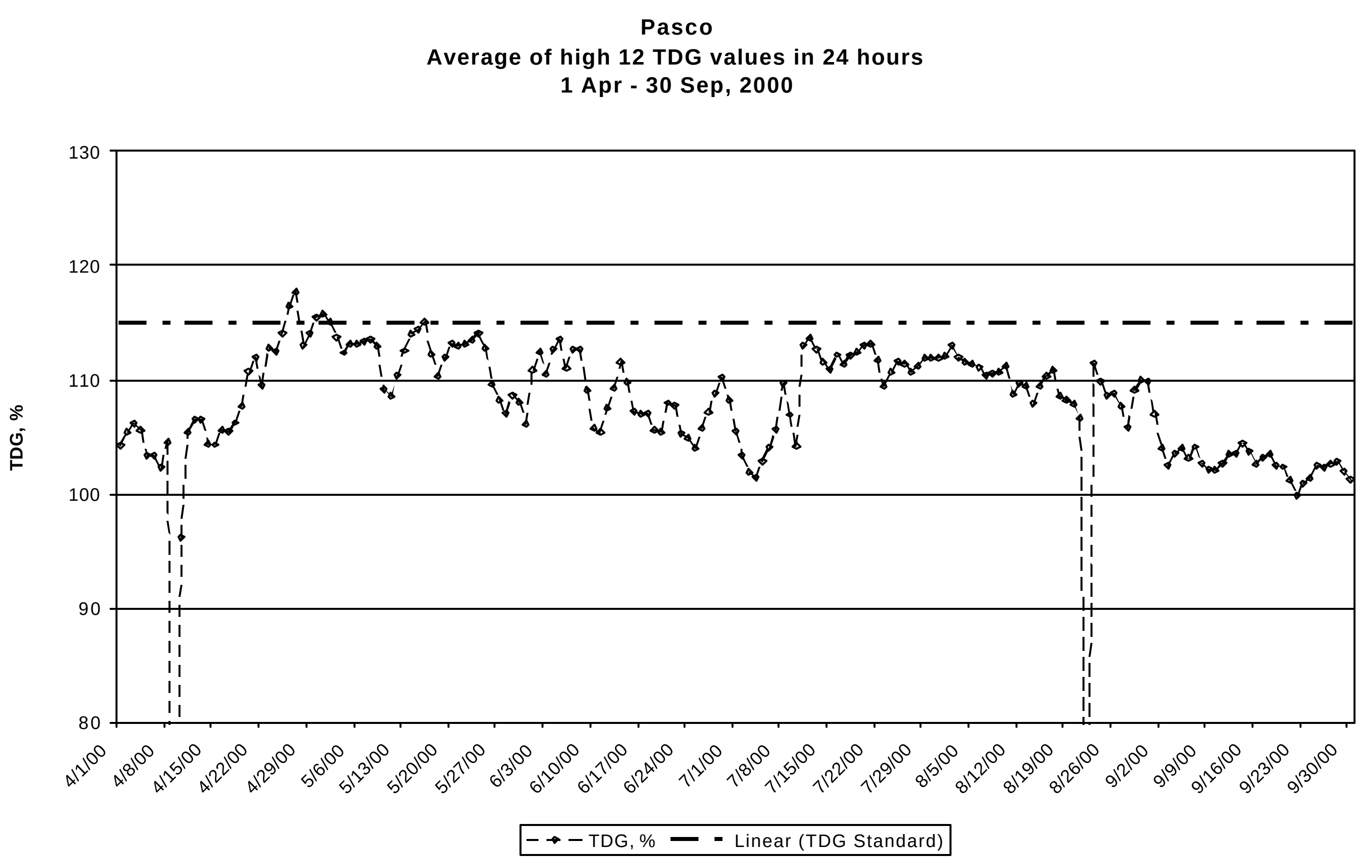


Ice Harbor Forebay
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000



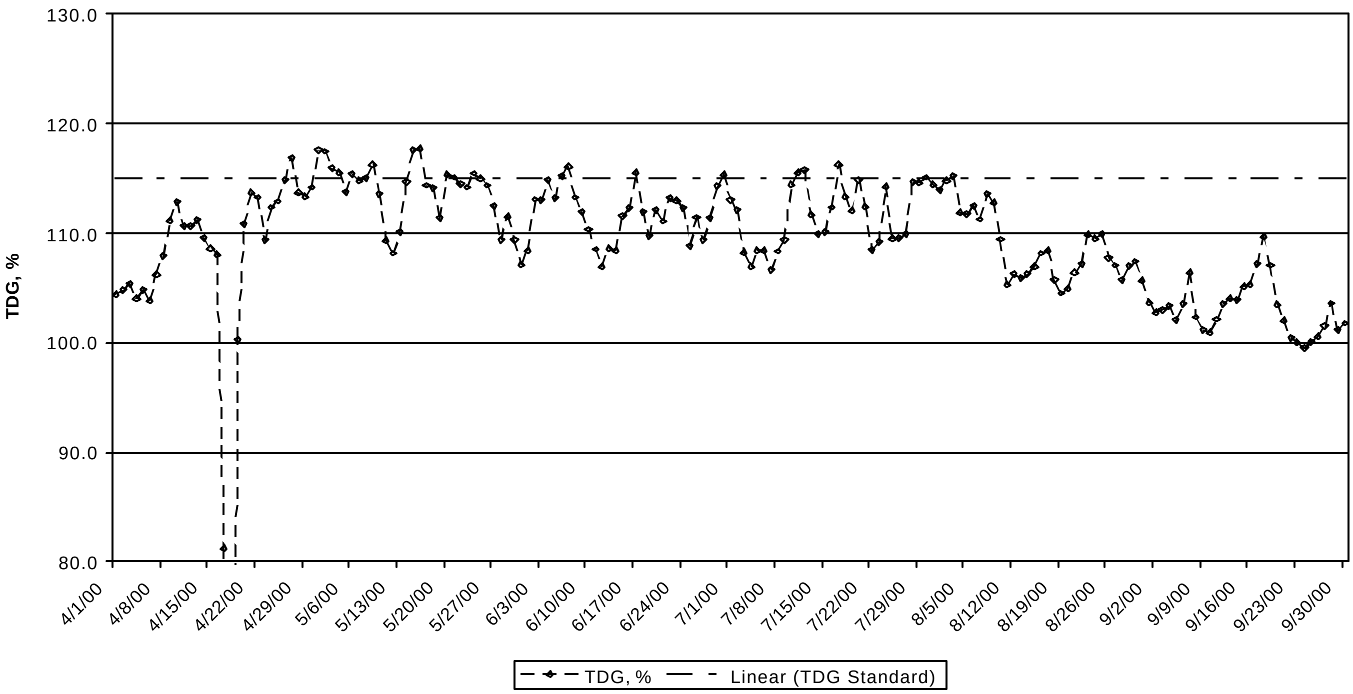


Ice Harbor Tailwater
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000
130
120
110
100
90
80
TDG, %
4/1/00
4/8/00
4/15/00
4/22/00
4/29/00
5/6/00
5/13/00
5/20/00
5/27/00
6/3/00
6/10/00
6/17/00
6/24/00
7/1/00
7/8/00
7/15/00
7/22/00
7/29/00
8/5/00
8/12/00
8/19/00
8/26/00
9/2/00
9/9/00
9/16/00
9/23/00
9/30/00
TDG, %
Linear (TDG Standard)

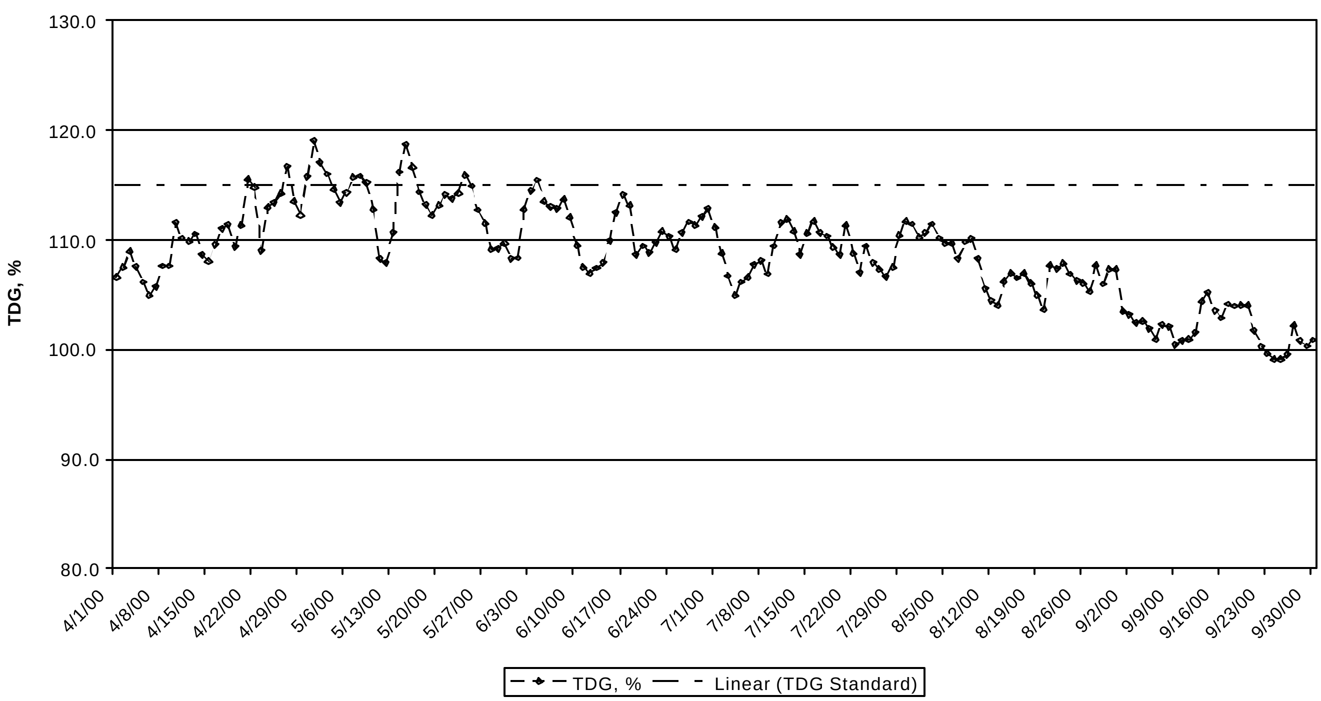


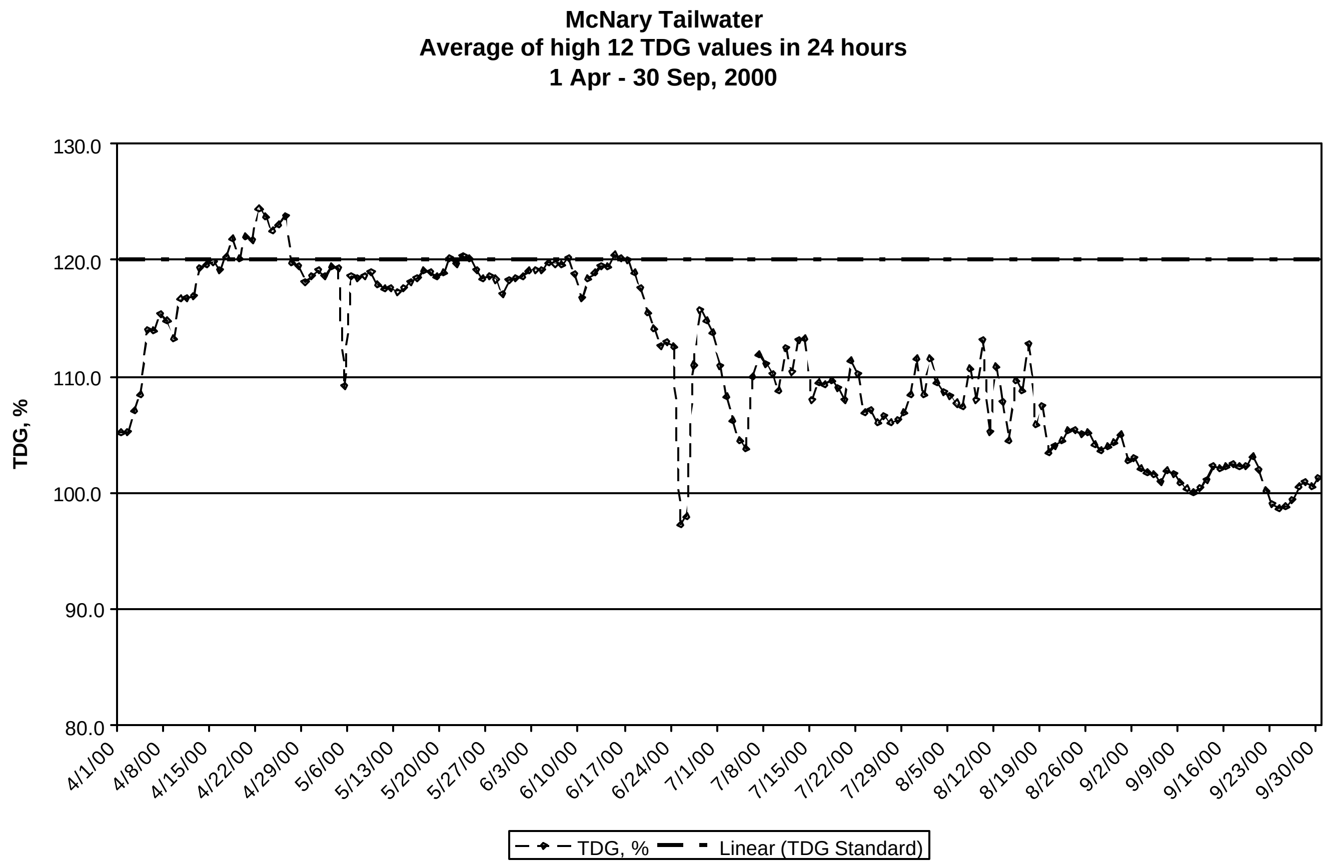
Pasco
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000
130
120
110
100
90
80
TDG, %
4/1/00
4/8/00
4/15/00
4/22/00
4/29/00
5/6/00
5/13/00
5/20/00
5/27/00
6/3/00
6/10/00
6/17/00
6/24/00
7/1/00
7/8/00
7/15/00
7/22/00
7/29/00
8/5/00
8/12/00
8/19/00
8/26/00
9/2/00
9/9/00
9/16/00
9/23/00
9/30/00
TDG, %
Linear (TDG Standard)

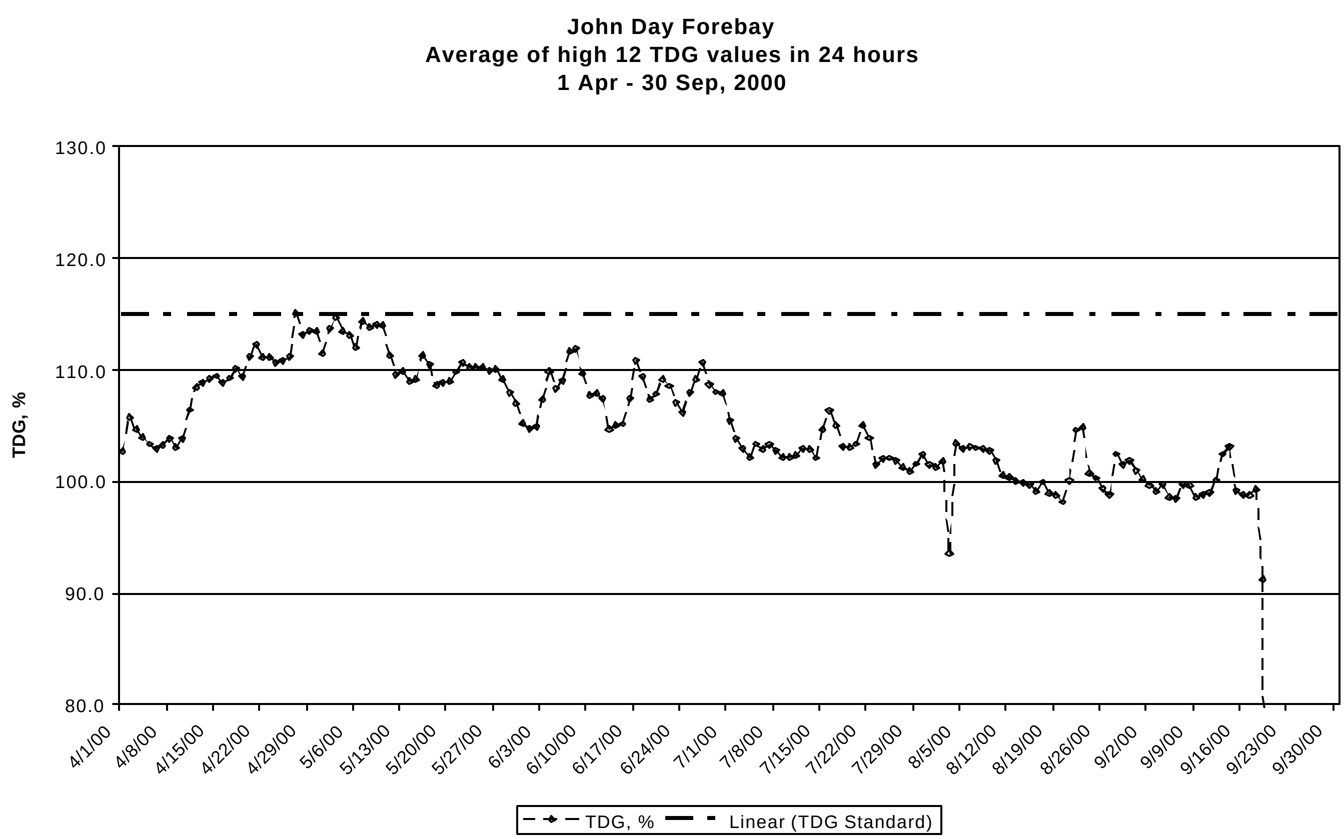
McNary Oregon Forebay
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000



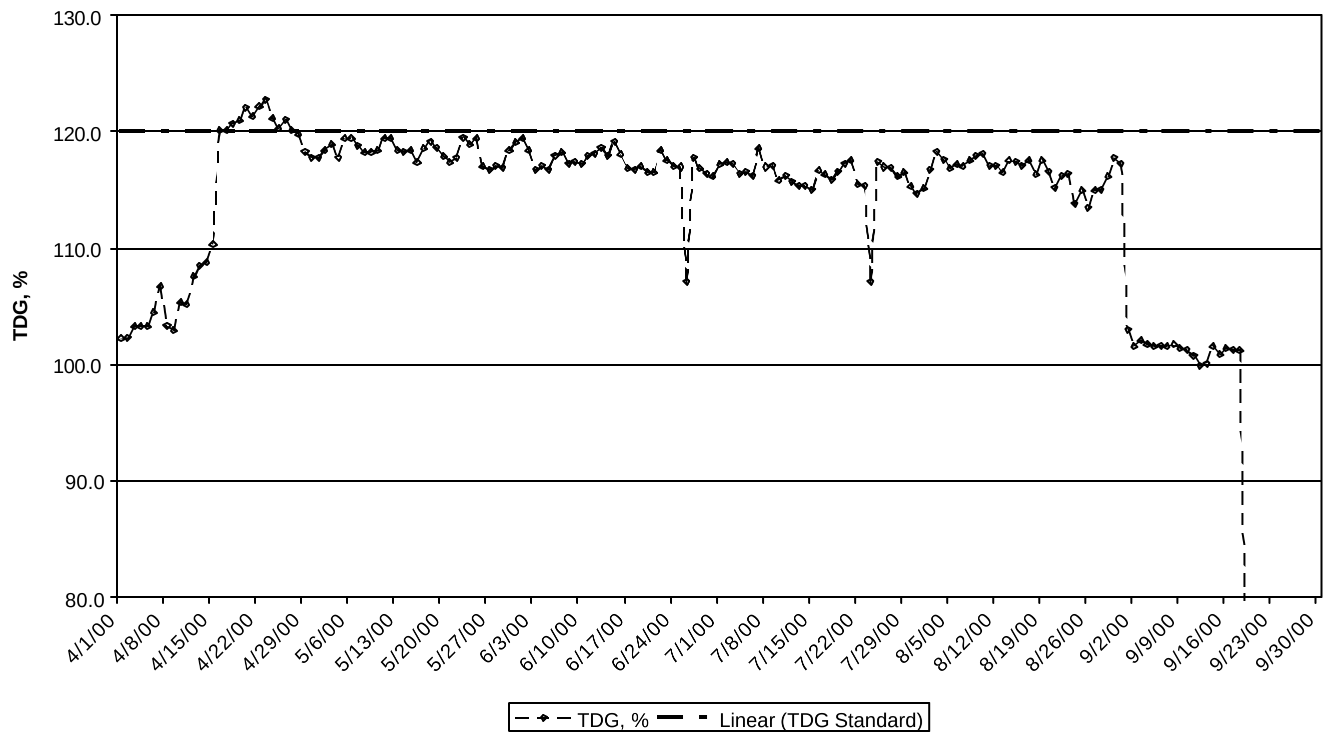
McNary Washington Forebay
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000



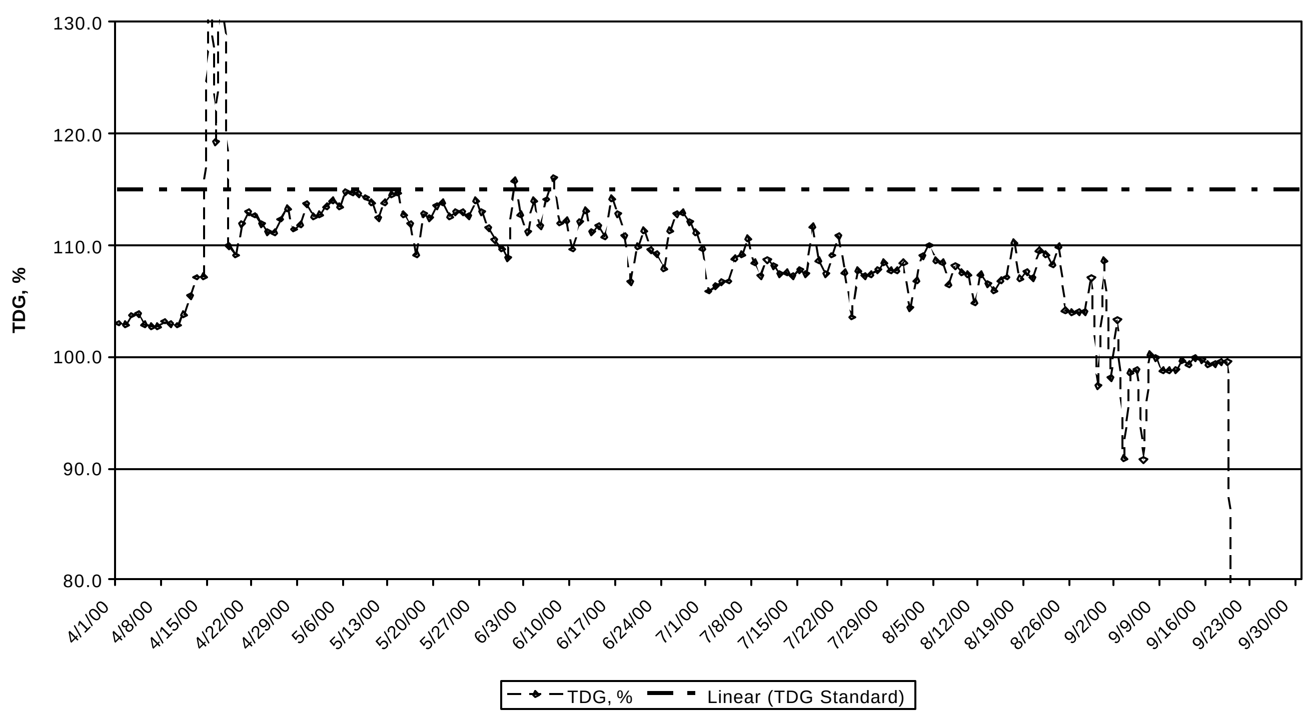

McNary Tailwater
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000
TDG, %
130.0
120.0
110.0
100.0
90.0
80.0
4/1/00
4/8/00
4/15/00
4/22/00
4/29/00
5/6/00
5/13/00
5/20/00
5/27/00
6/3/00
6/10/00
6/17/00
6/24/00
7/1/00
7/8/00
7/15/00
7/22/00
7/29/00
8/5/00
8/12/00
8/19/00
8/26/00
9/2/00
9/9/00
9/16/00
9/23/00
9/30/00
TDG, %
Linear (TDG Standard)


John Day Forebay
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000
TDG, %
130.0
120.0
110.0
100.0
90.0
80.0
4/1/00
4/8/00
4/15/00
4/22/00
4/29/00
5/6/00
5/13/00
5/20/00
5/27/00
6/3/00
6/10/00
6/17/00
6/24/00
7/1/00
7/8/00
7/15/00
7/22/00
7/29/00
8/5/00
8/12/00
8/19/00
8/26/00
9/2/00
9/9/00
9/16/00
9/23/00
9/30/00
TDG, %
Linear (TDG Standard)

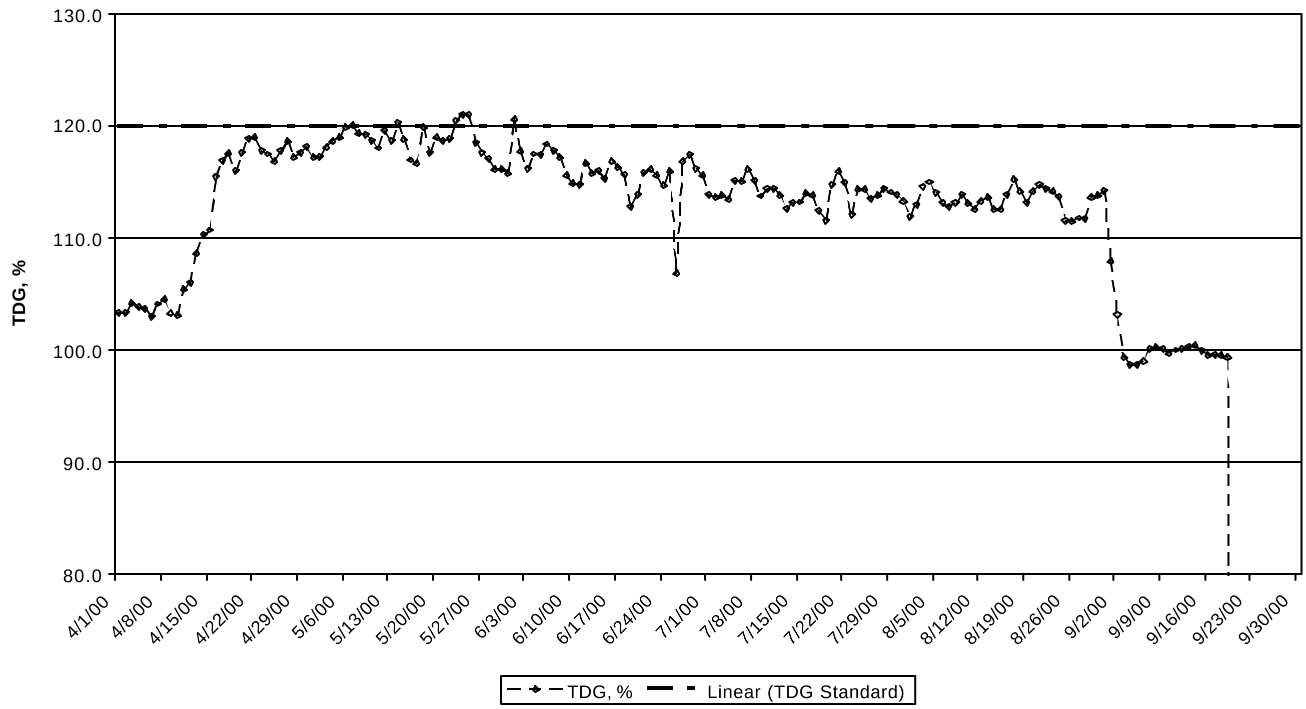
John Day Tailwater
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000



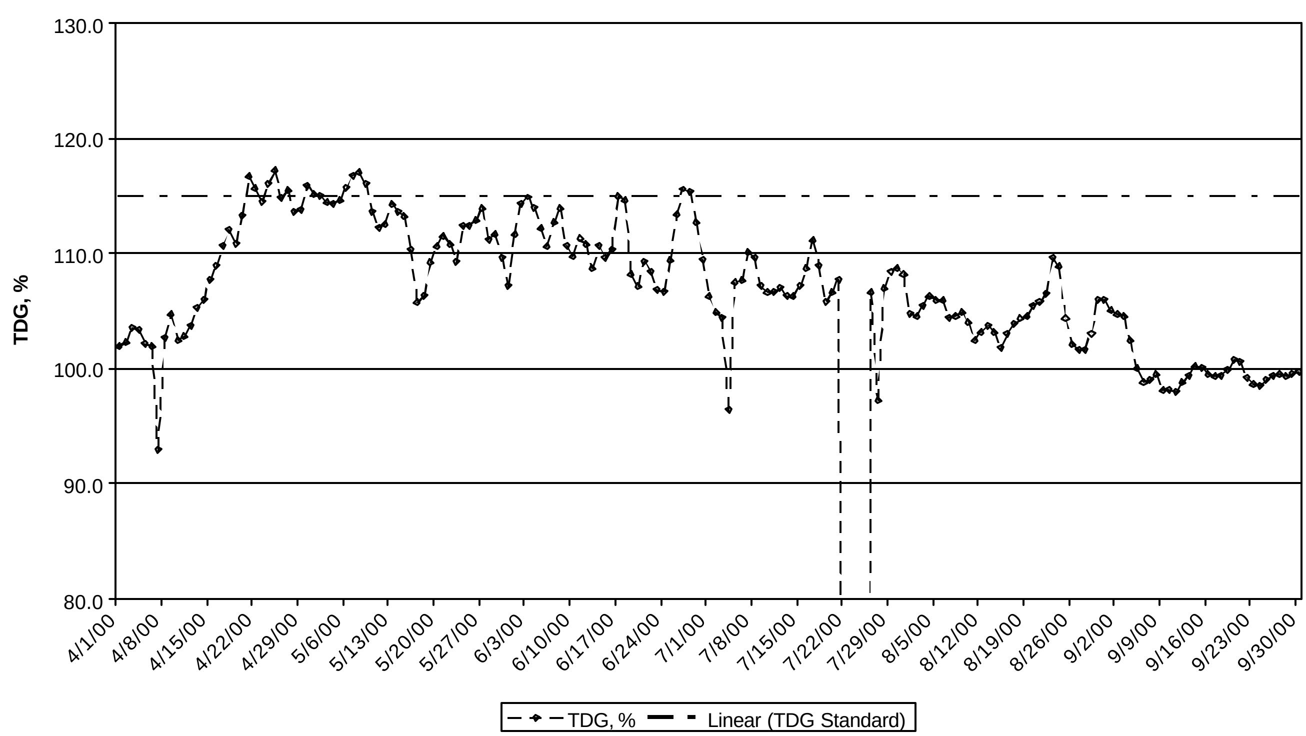
The Dalles Forebay
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000

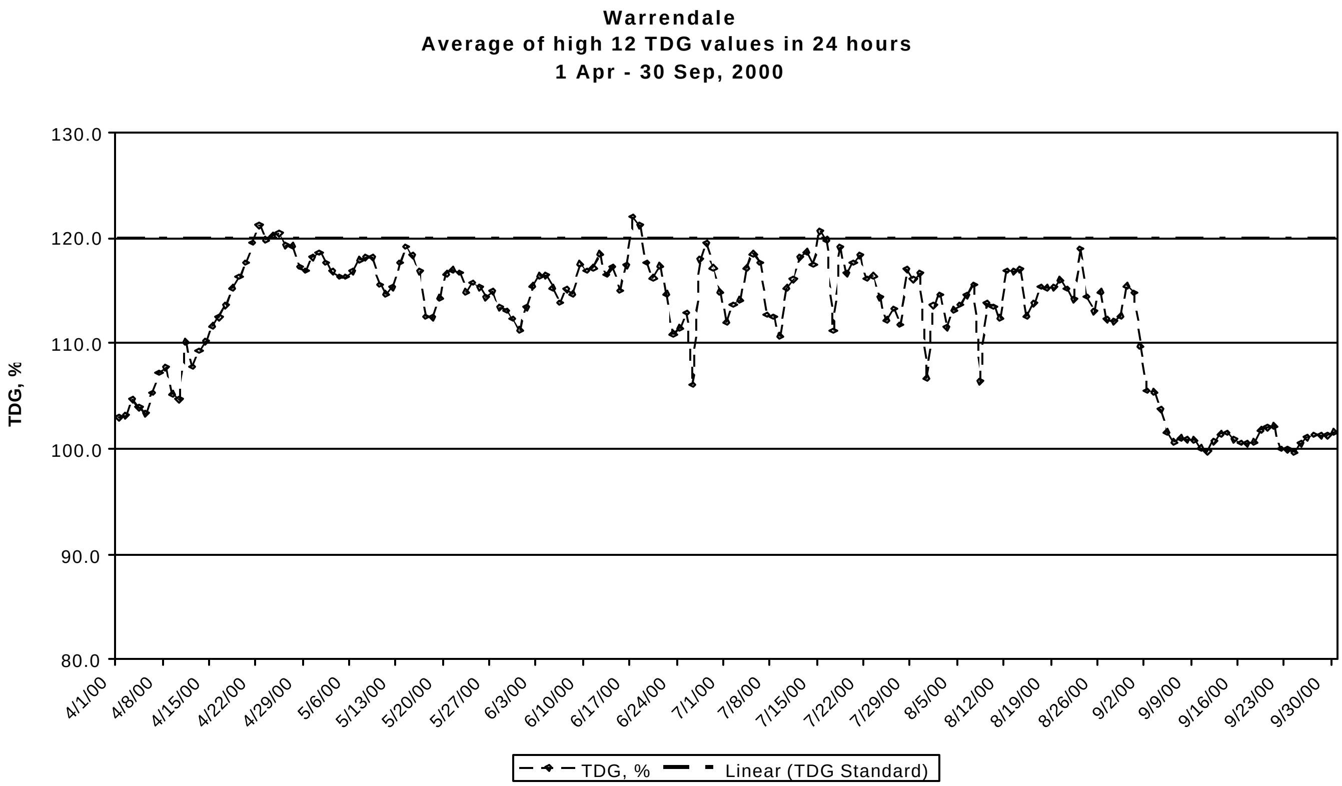


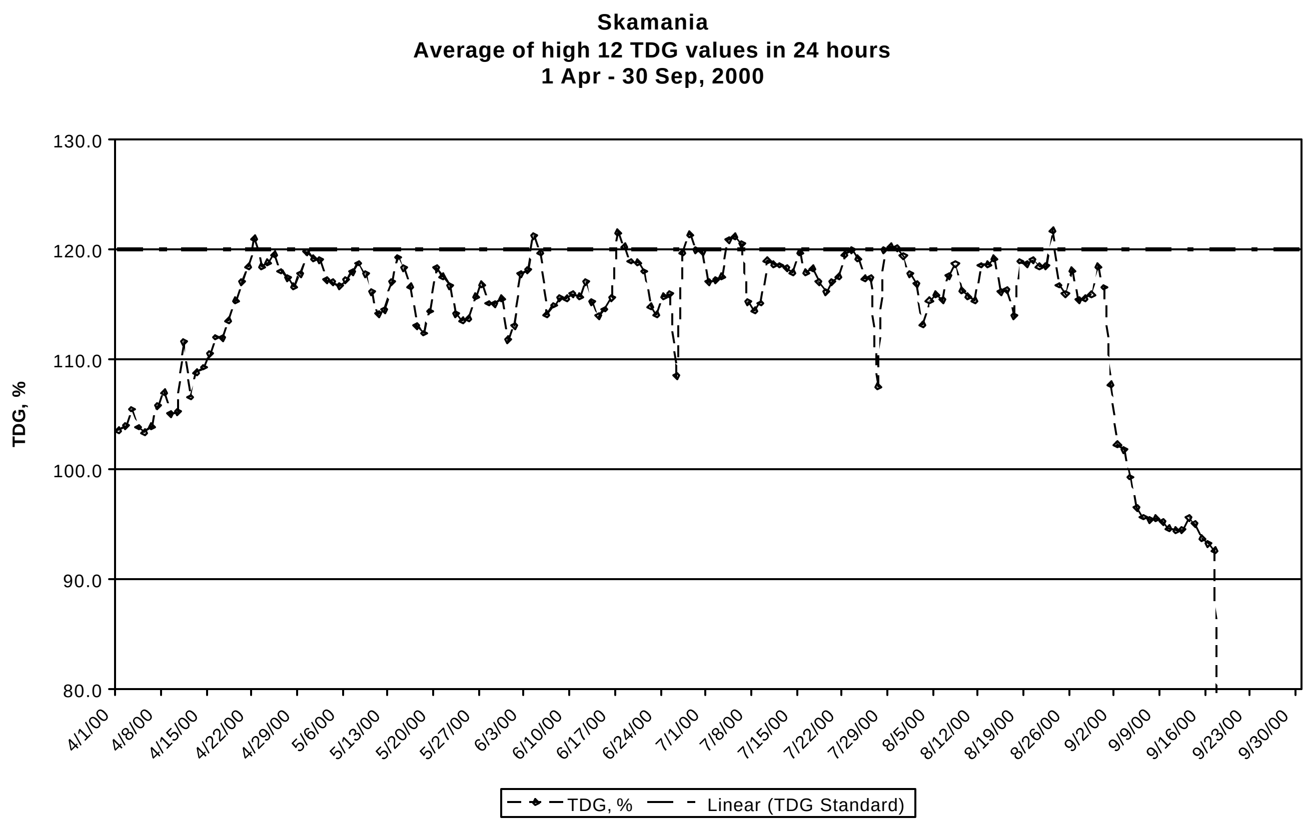
The Dalles Tailwater
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000

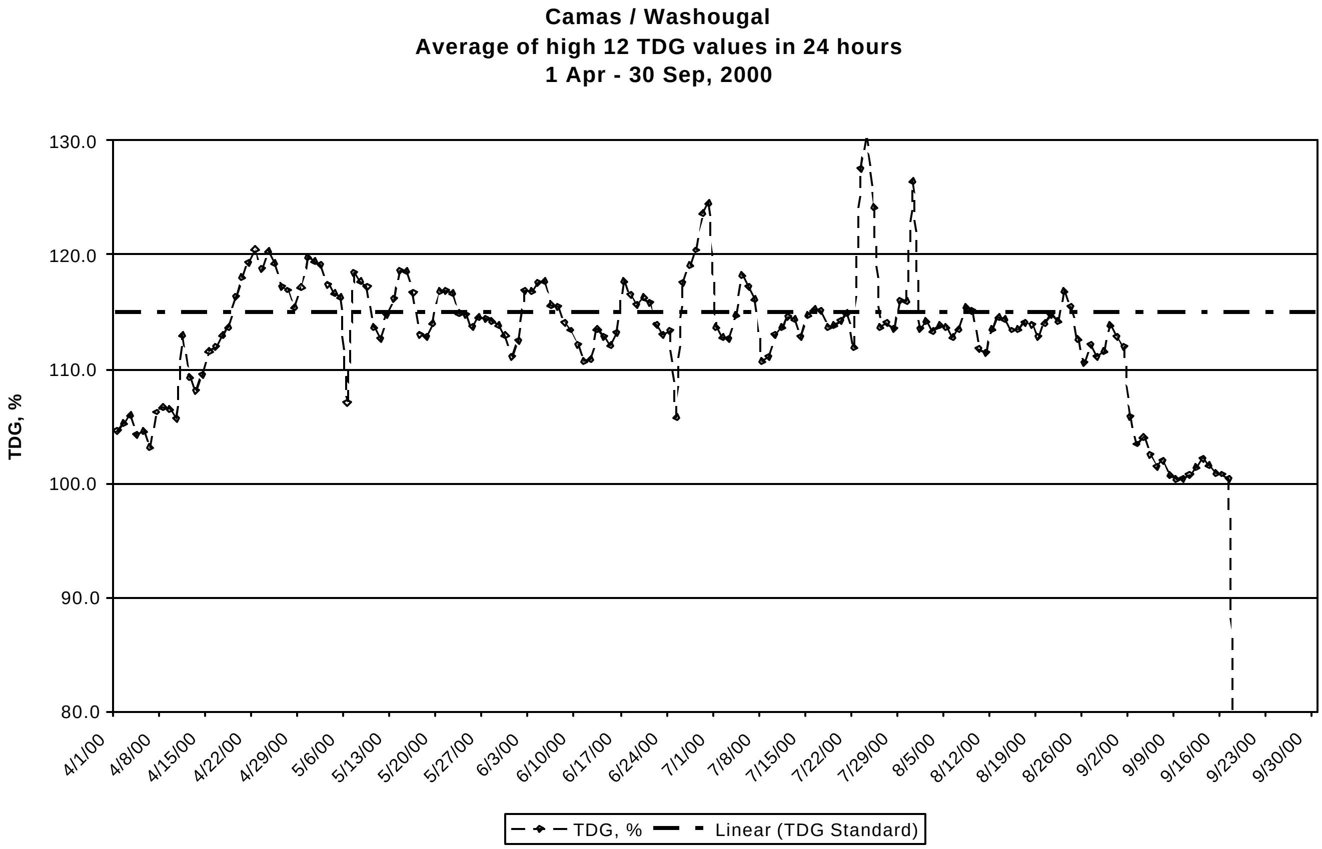


Bonneville Forebay
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000




Warrendale
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000
TDG, %
130.0
120.0
110.0
100.0
90.0
80.0
4/1/00
4/8/00
4/15/00
4/22/00
4/29/00
5/6/00
5/13/00
5/20/00
5/27/00
6/3/00
6/10/00
6/17/00
6/24/00
7/1/00
7/8/00
7/15/00
7/22/00
7/29/00
8/5/00
8/12/00
8/19/00
8/26/00
9/2/00
9/9/00
9/16/00
9/23/00
9/30/00
TDG, %
Linear (TDG Standard)

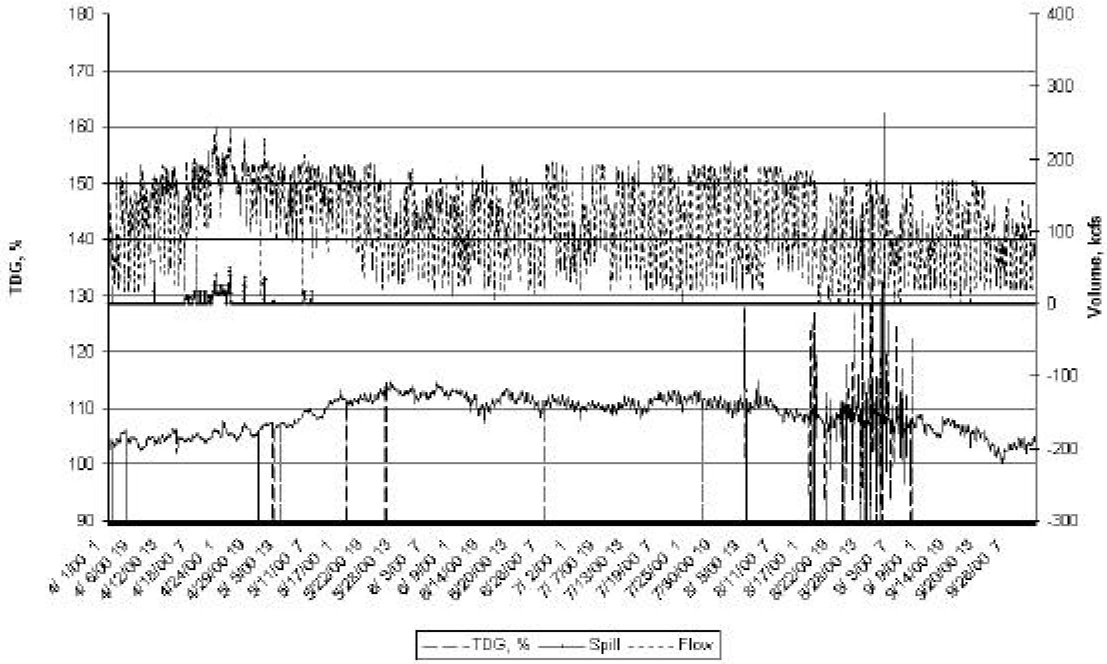

Skamania
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000
TDG, %
130.0
120.0
110.0
100.0
90.0
80.0
4/1/00
4/8/00
4/15/00
4/22/00
4/29/00
5/6/00
5/13/00
5/20/00
5/27/00
6/3/00
6/10/00
6/17/00
6/24/00
7/1/00
7/8/00
7/15/00
7/22/00
7/29/00
8/5/00
8/12/00
8/19/00
8/26/00
9/2/00
9/9/00
9/16/00
9/23/00
9/30/00
TDG, %
Linear (TDG Standard)



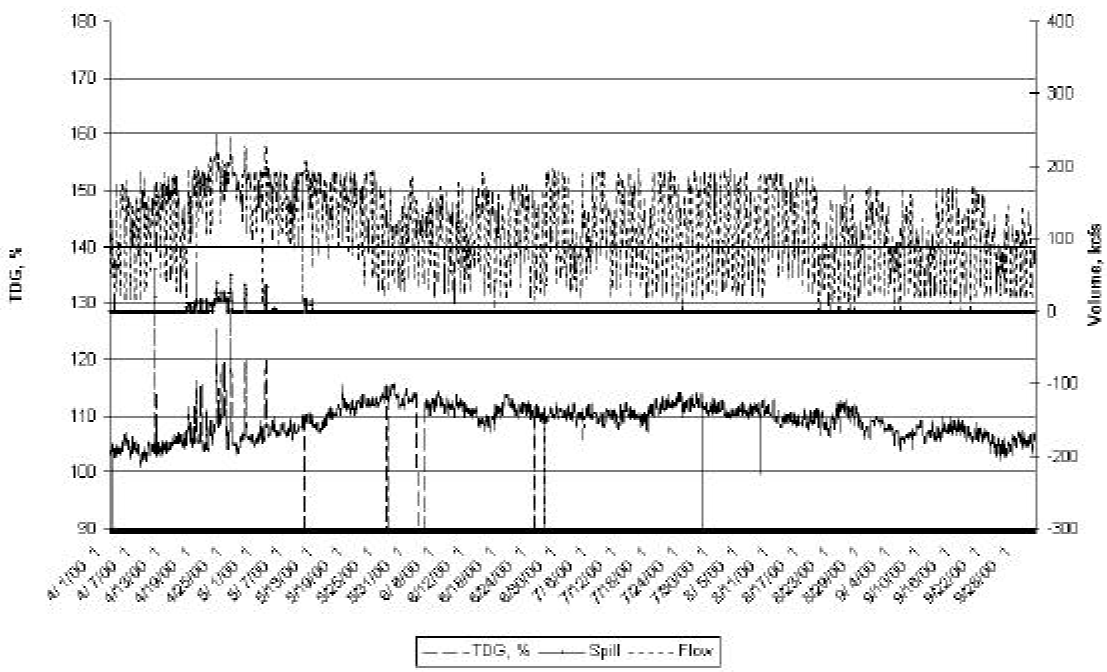
Camas / Washougal
Average of high 12 TDG values in 24 hours
1 Apr - 30 Sep, 2000
130.0
120.0
110.0
100.0
90.0
80.0
TDG, %
4/1/00
4/8/00
4/15/00
4/22/00
4/29/00
5/6/00
5/13/00
5/20/00
5/27/00
6/3/00
6/10/00
6/17/00
6/24/00
7/1/00
7/8/00
7/15/00
7/22/00
7/29/00
8/5/00
8/12/00
8/19/00
8/26/00
9/2/00
9/9/00
9/16/00
9/23/00
9/30/00
TDG, %
Linear (TDG Standard)

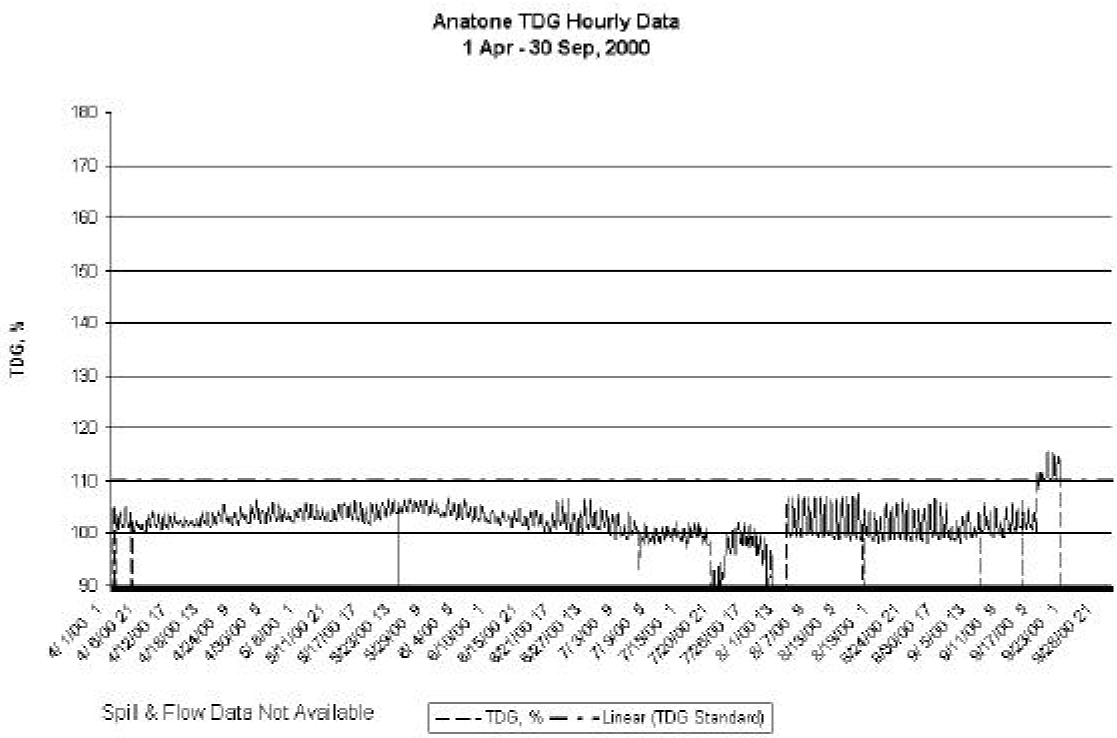
Appendix F
TDG data graphs
Hourly spill, flow and TDG

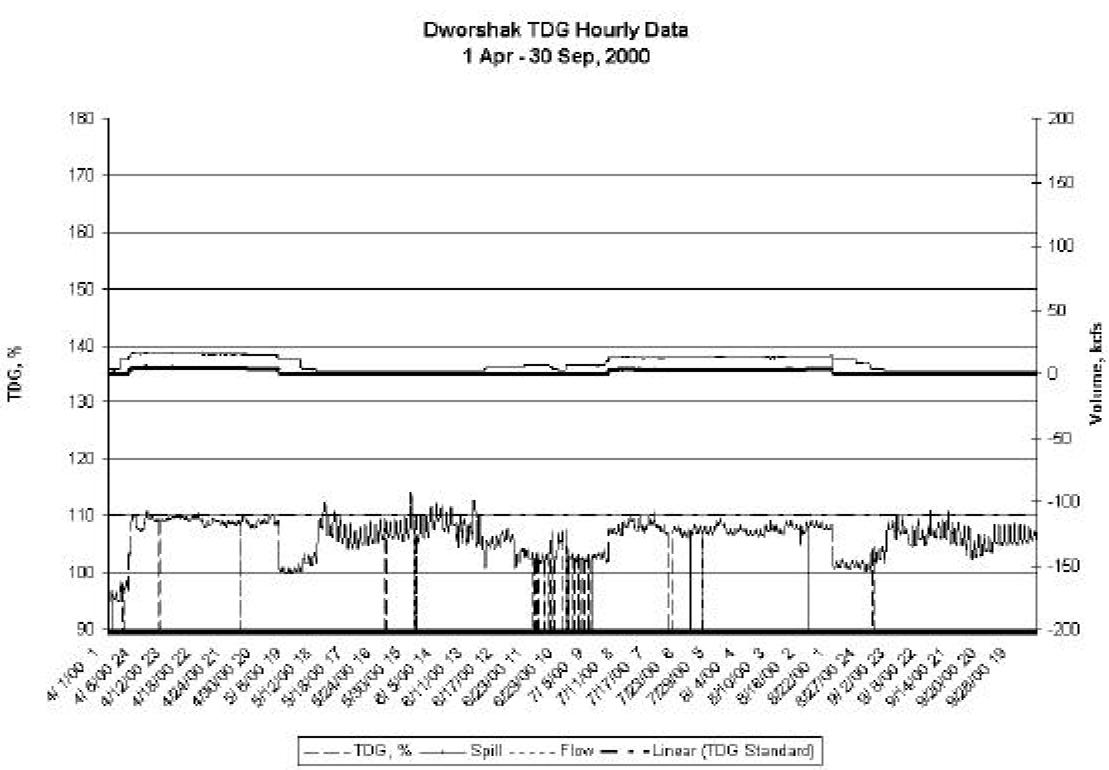
Chief Joseph Forebay TDG Hourly Data
1 Apr - 30 Sep, 2000



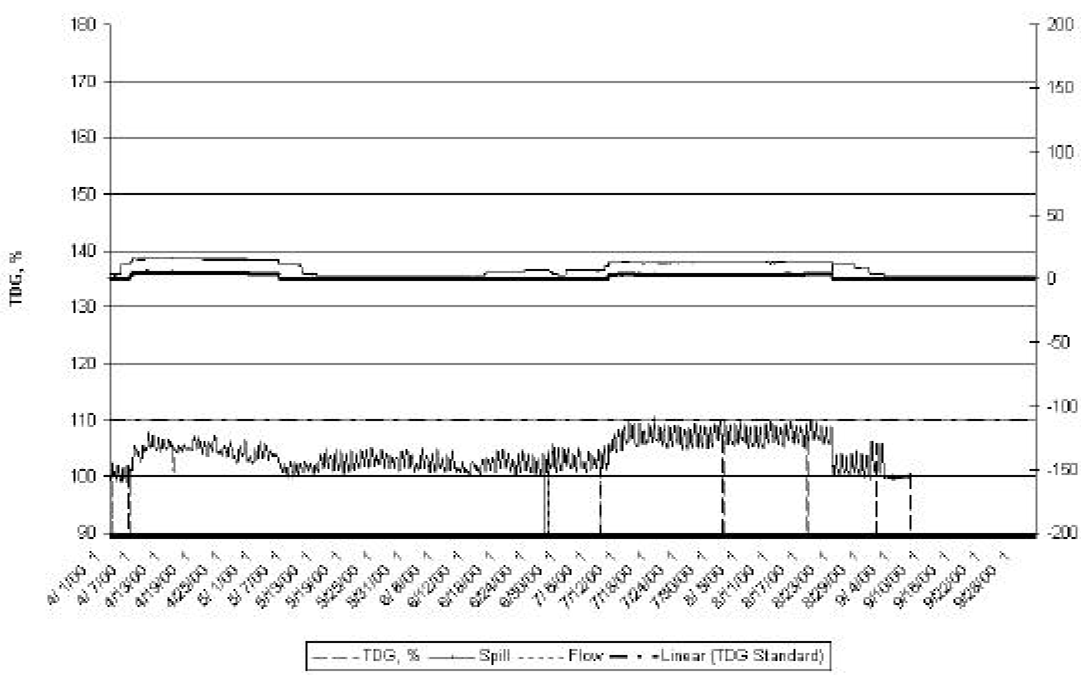
Chief Joseph Tailwater TDG Hourly Data
1 Apr - 30 Sep, 2000



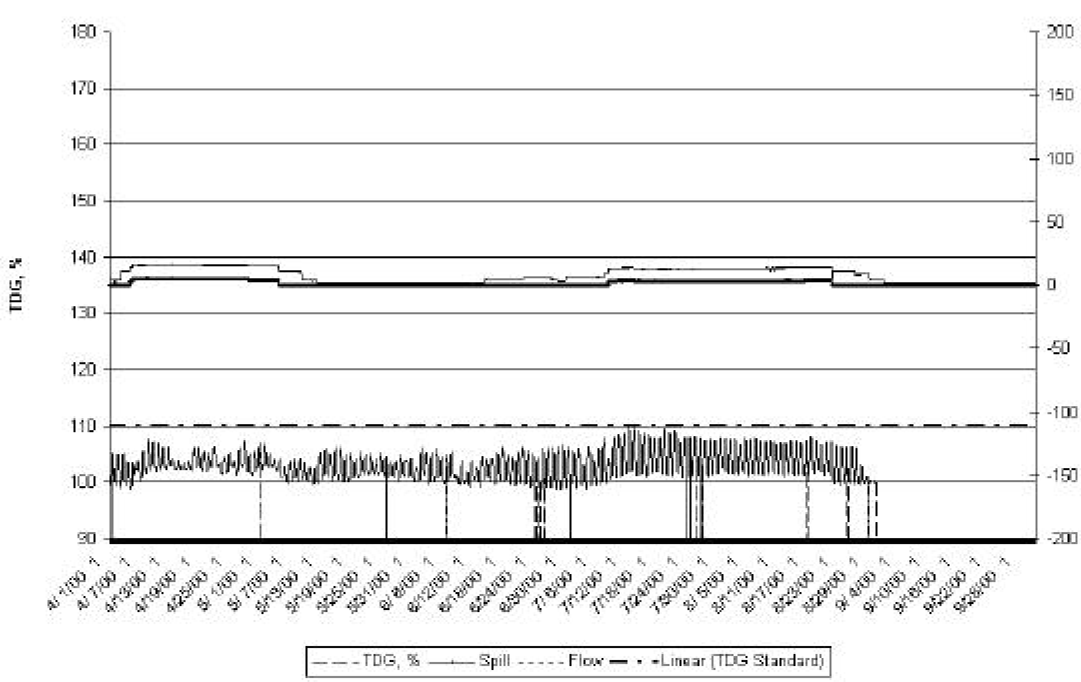

Anatone TDG Hourly Data
1 Apr - 30 Sep, 2000
TDG, %
Spill & Flow Data Not Available
TDG, %
Linear (TDG Standard)


Dworshak TDG Hourly Data
1 Apr - 30 Sep, 2000
TDG, %
Volume, kcfs
TDG, %
Spill
Flow
Linear (TDG Standard)

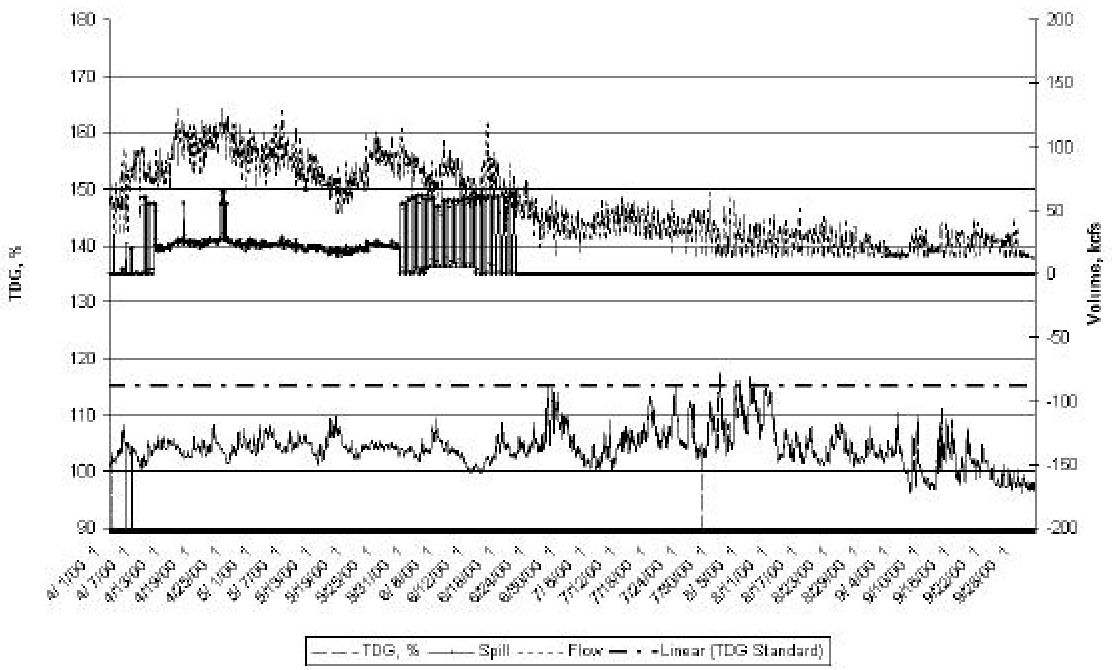
Peck TDG Hourly Data
1 Apr - 30 Sep, 2000



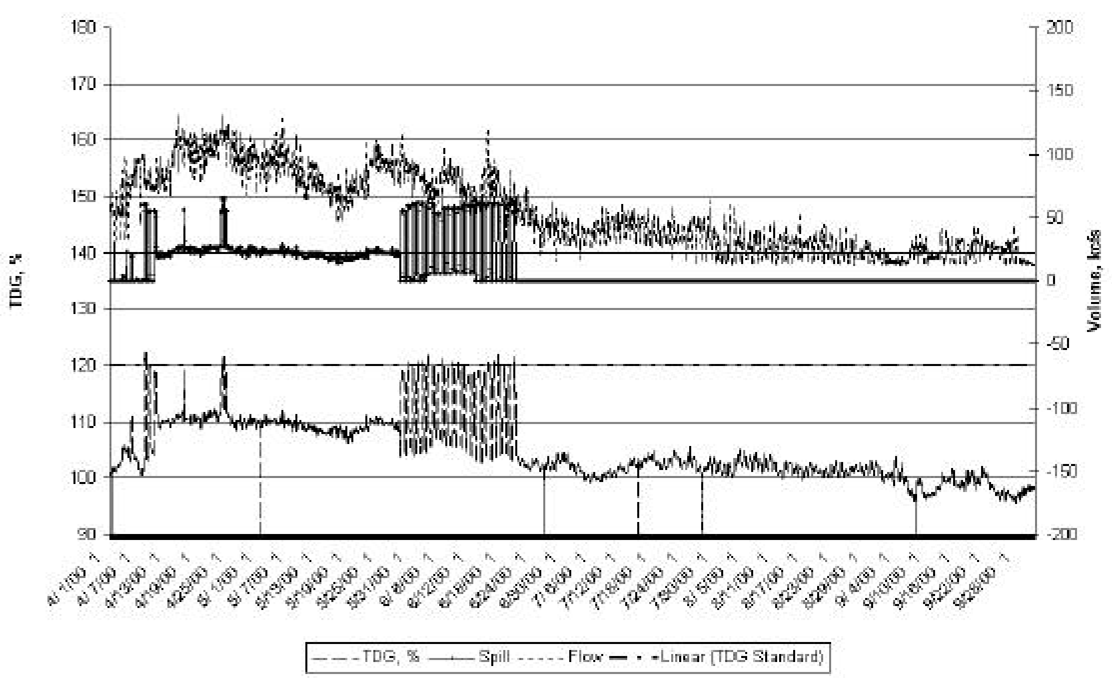
Lewiston TDG Hourly Data
1 Apr - 30 Sep, 2000



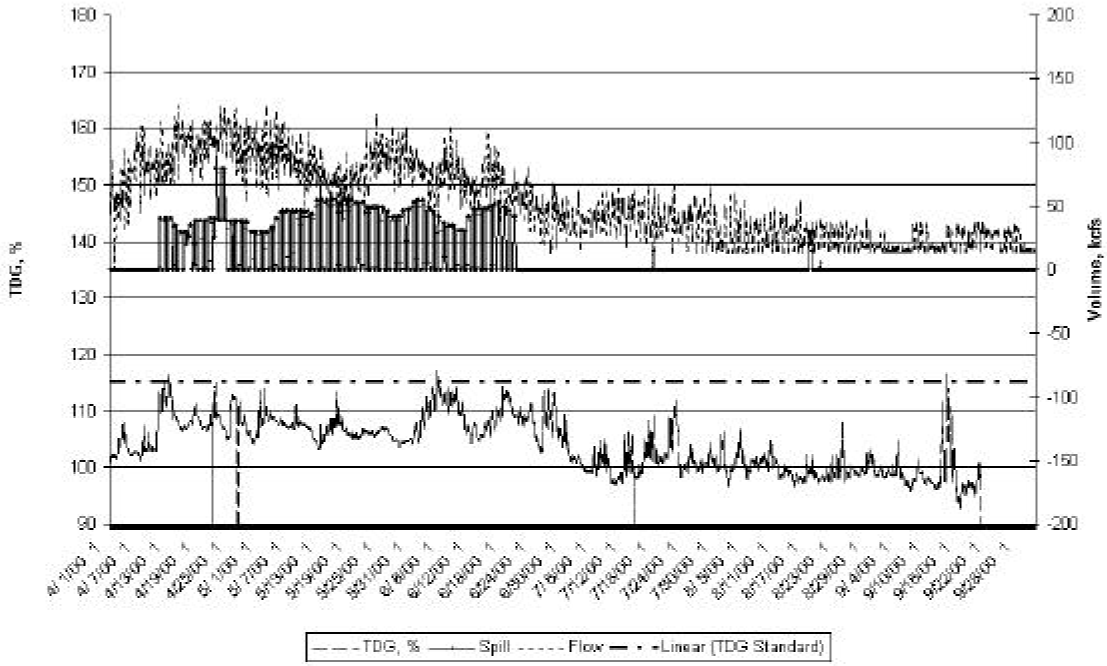
Lower Granite Forebay TDG Hourly Data
1 Apr, 1999 - 30 Sep, 2000



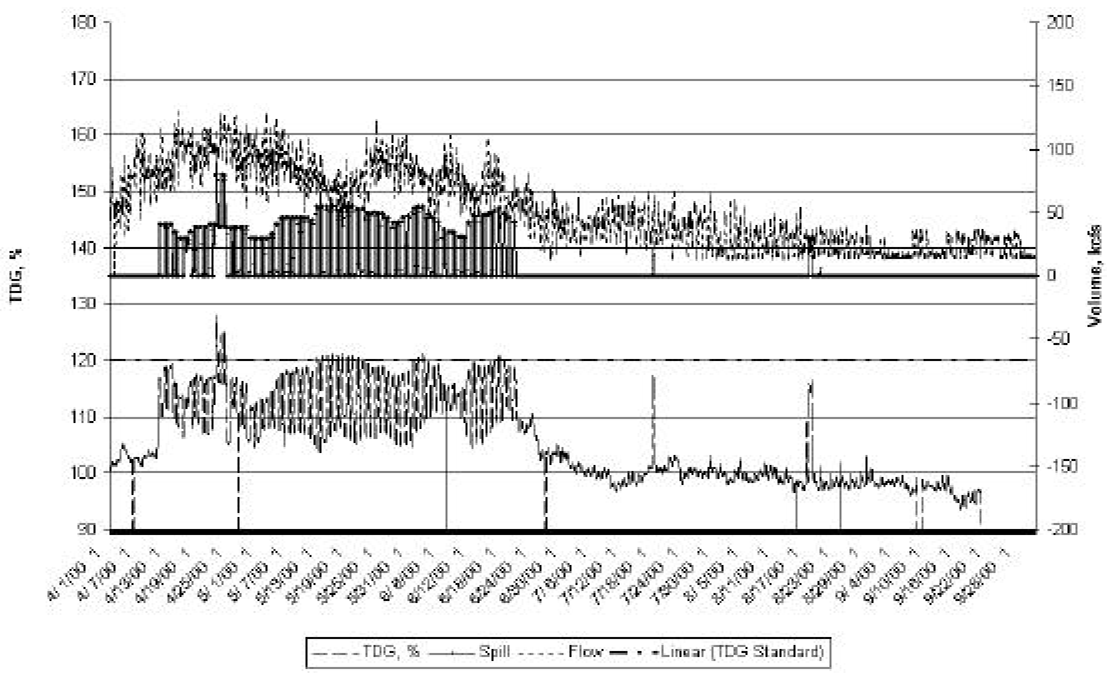
Lower Granite Tailwater TDG Hourly Data
1 Apr, 1999 - 30 Sep, 2000



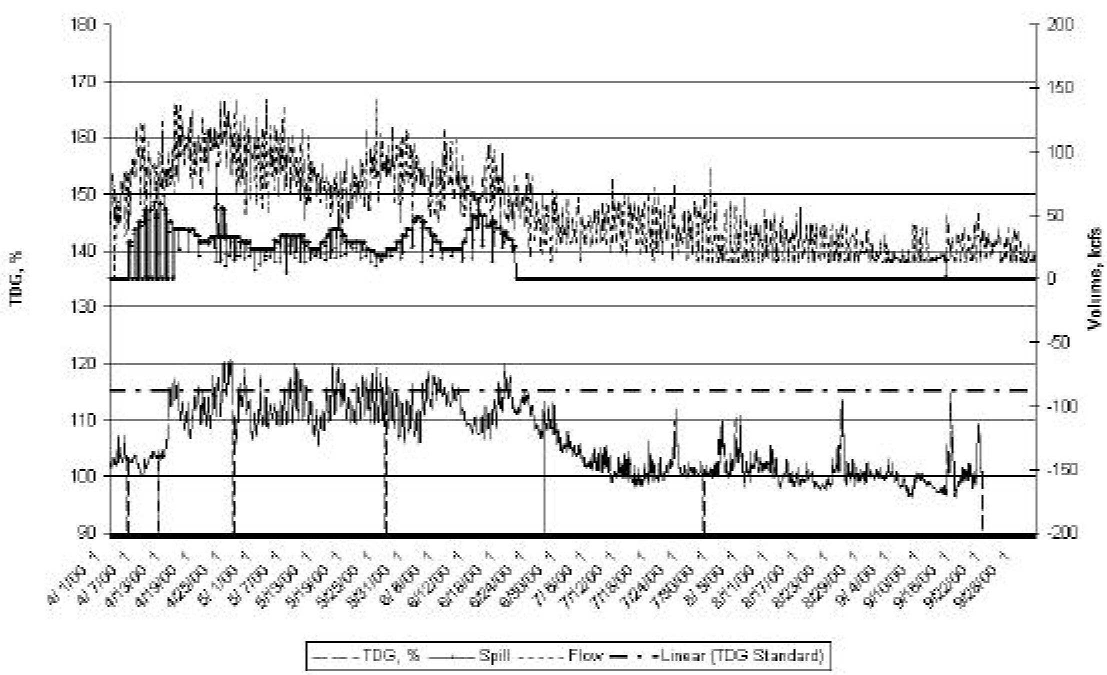
Little Goose Forebay TDG Hourly Data
1 Apr - 30 Sep, 2000



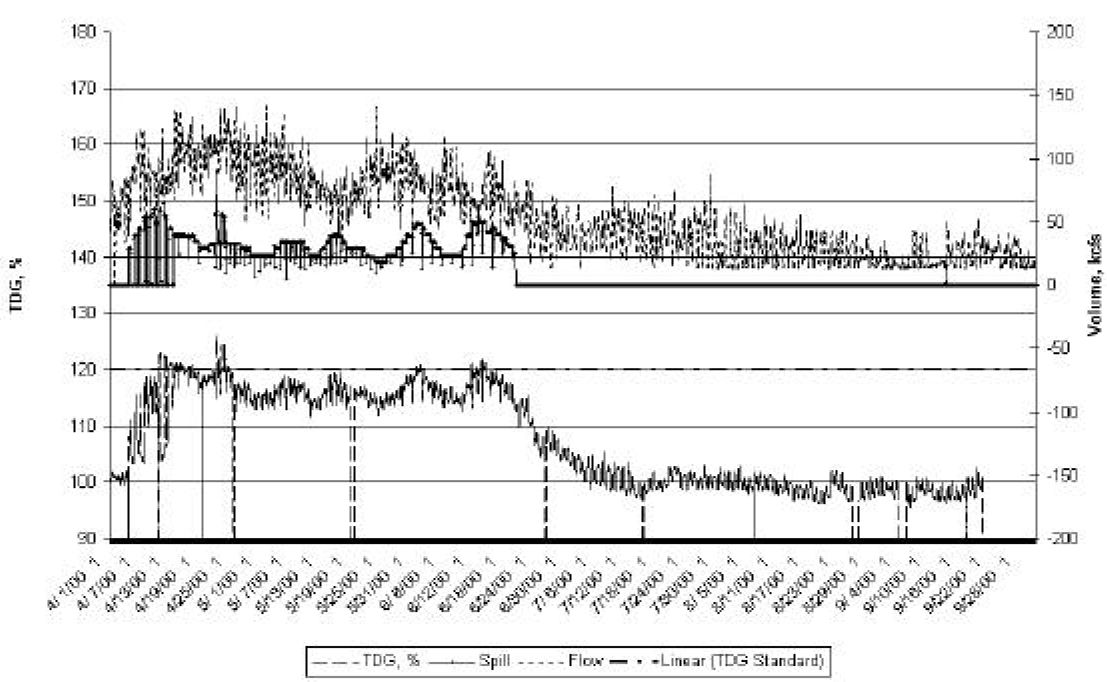
Little Goose Tailwater TDG Hourly Data
1 Apr - 30 Sep, 2000



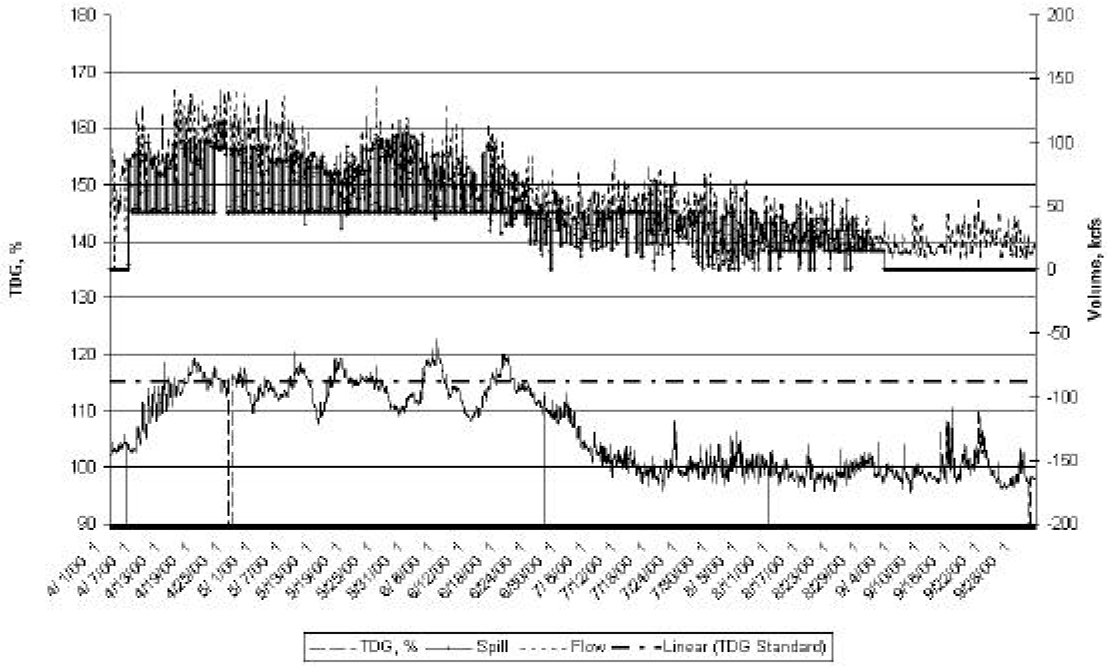
Lower Monumental Forebay TDG Hourly Data
1 Apr - 30 Sep, 2000



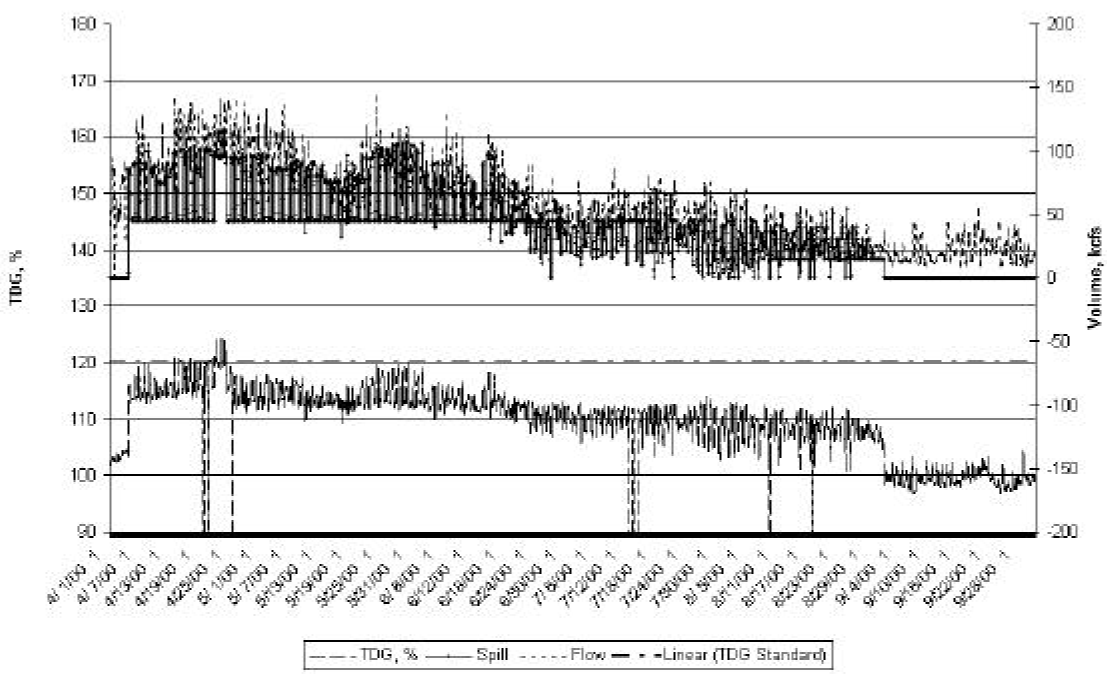
Lower Monumental Tailwater TDG Hourly Data
1 Apr - 30 Sep, 2000



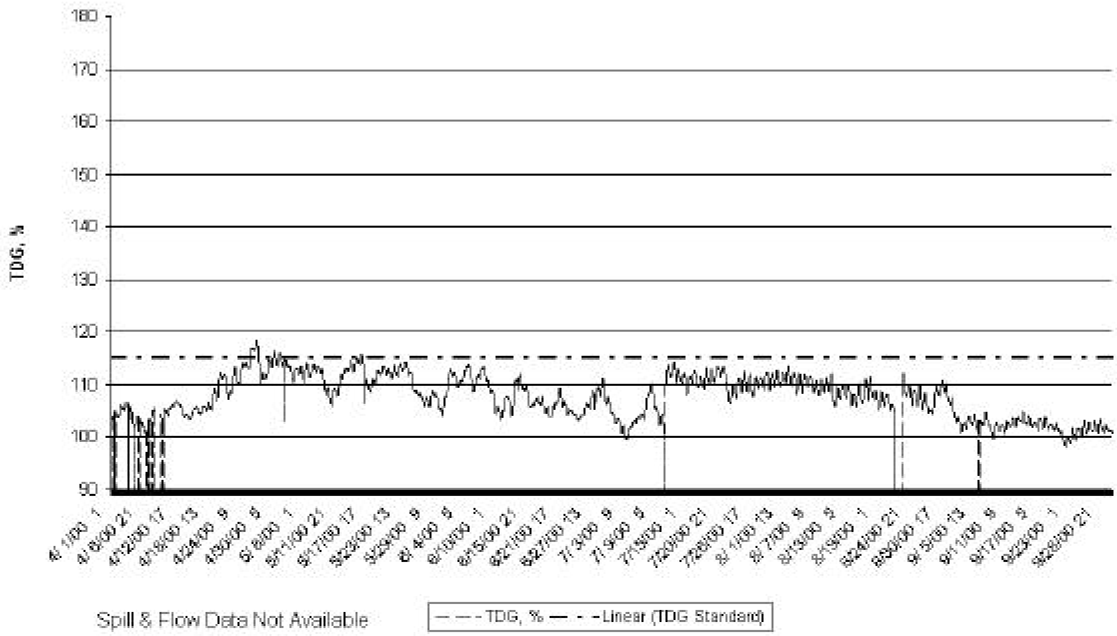
Ice Harbor Forebay TDG Hourly Data
1 Apr - 30 Sep, 2000



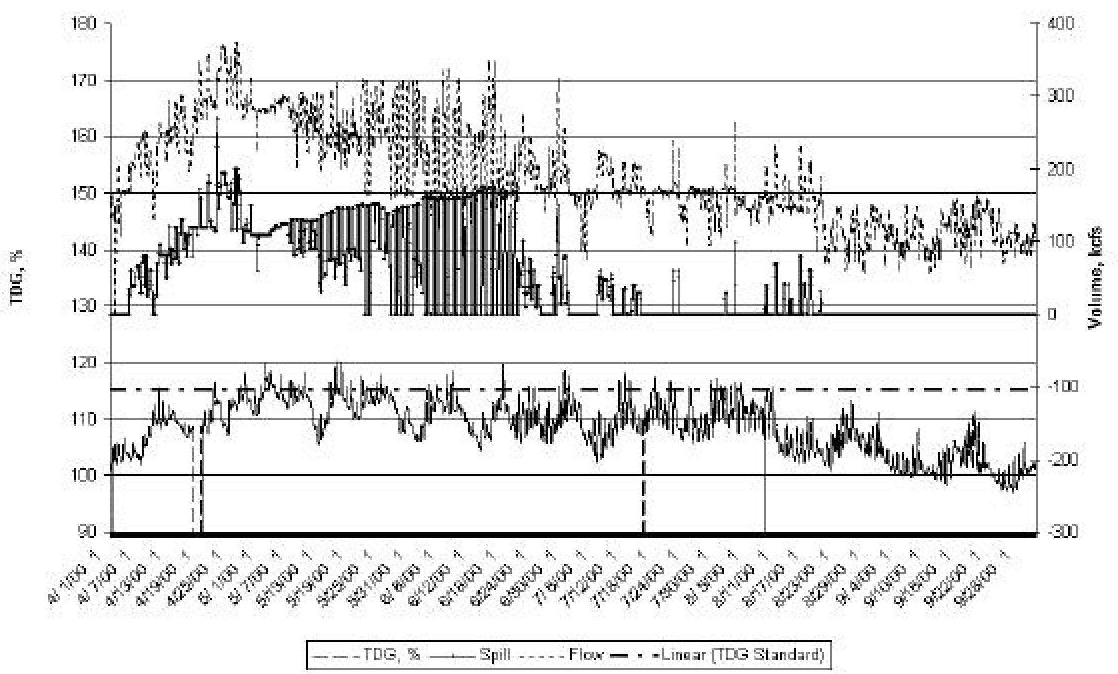
Ice Harbor Tailwater TDG Hourly Data
1 Apr - 30 Sep, 2000



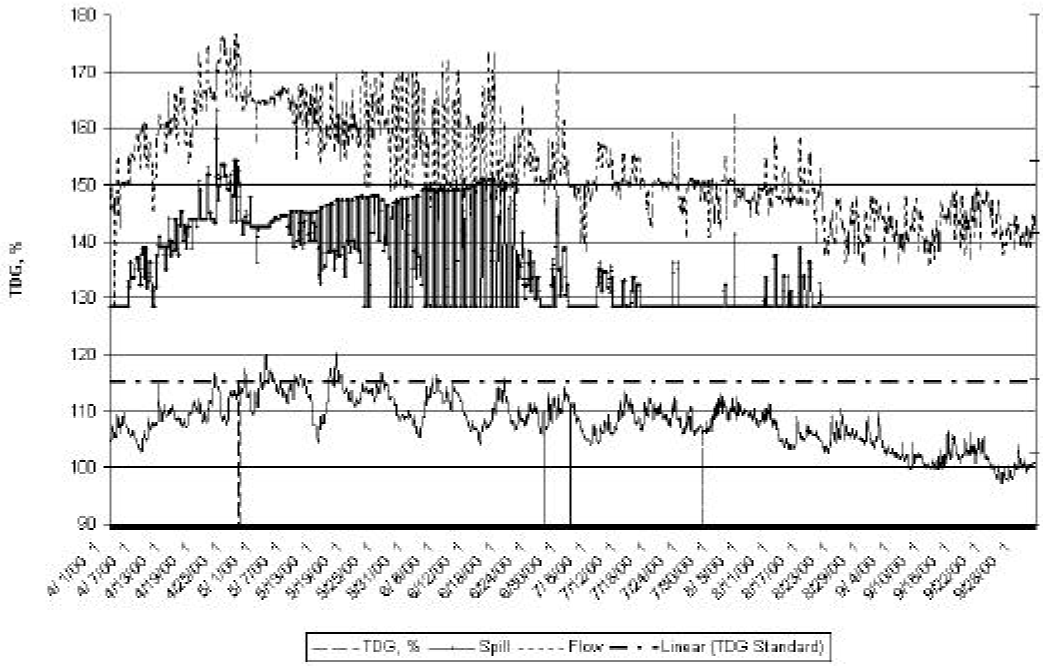
Pasco TDG Hourly Data
1 Apr - 30 Sep, 2000



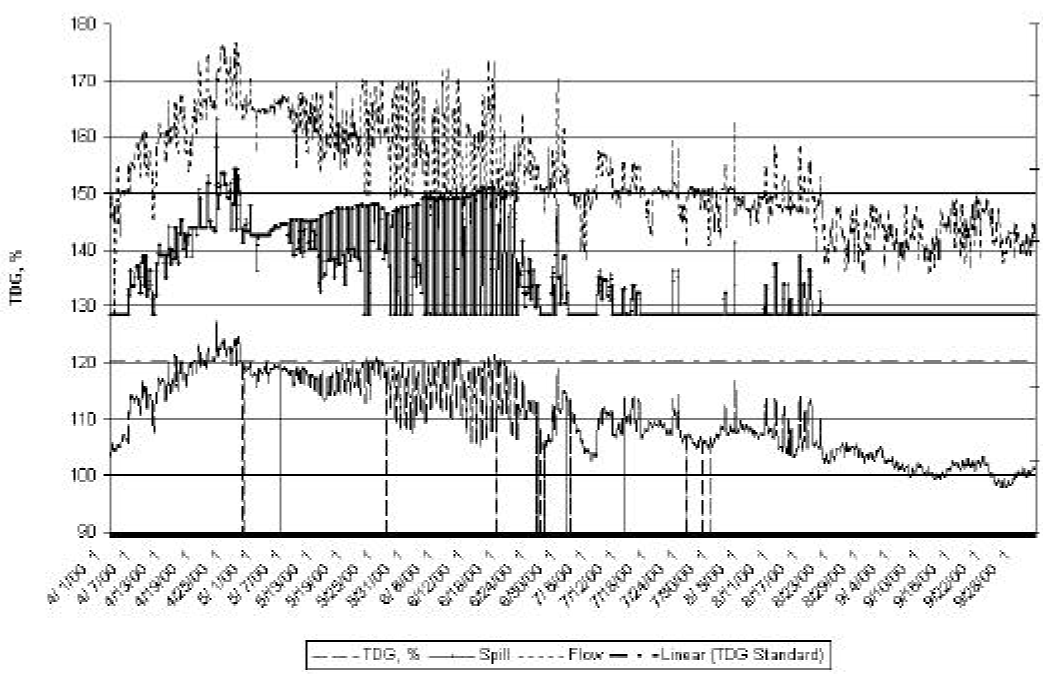
McNary Oregon Forebay TDG Hourly Data
1 Apr, 1999 - 30 Sep, 2000



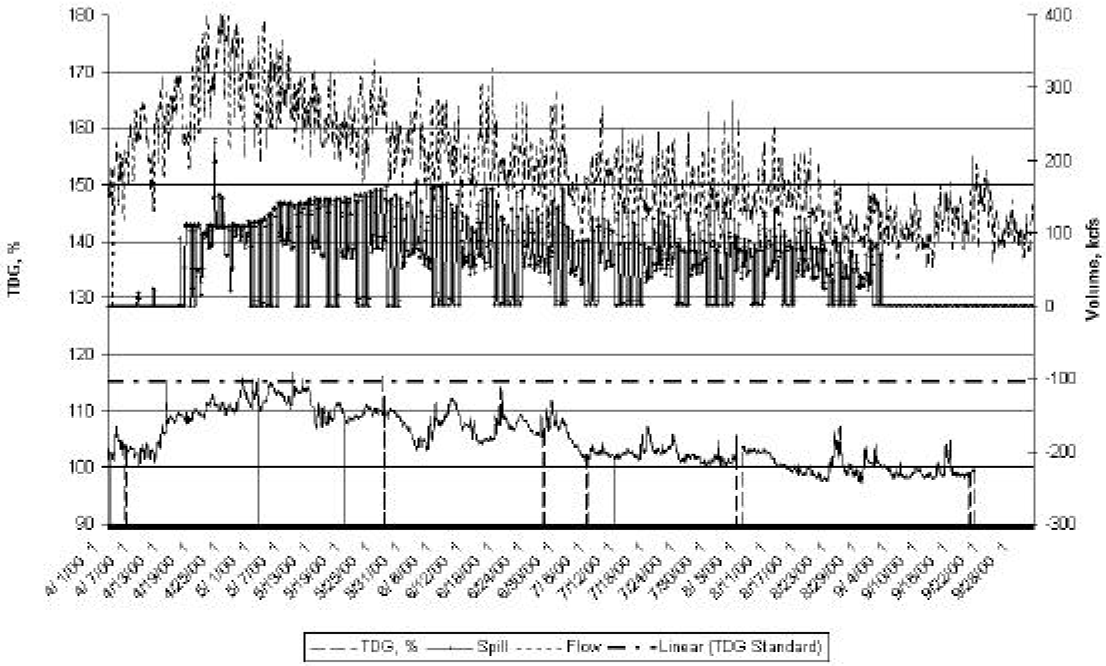
McNary Washington Forebay TDG Hourly Data
1 Apr, 1999 - 30 Sep, 2000



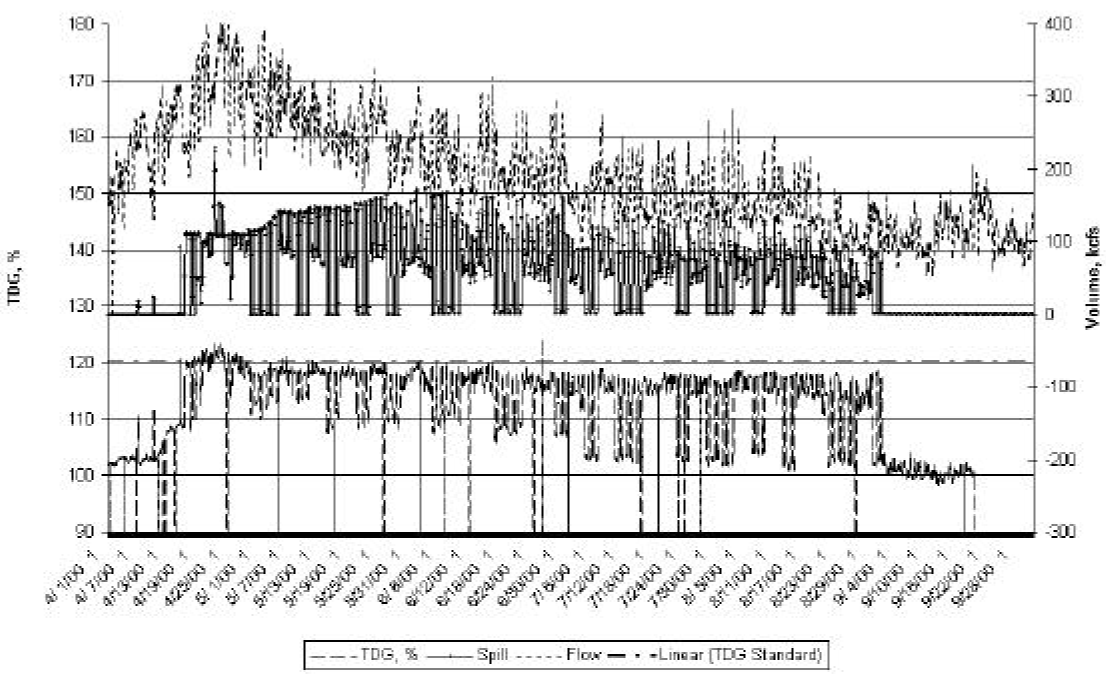
McNary Tailwater TDG Hourly Data
1 Apr, 1999 - 30 Sep, 2000



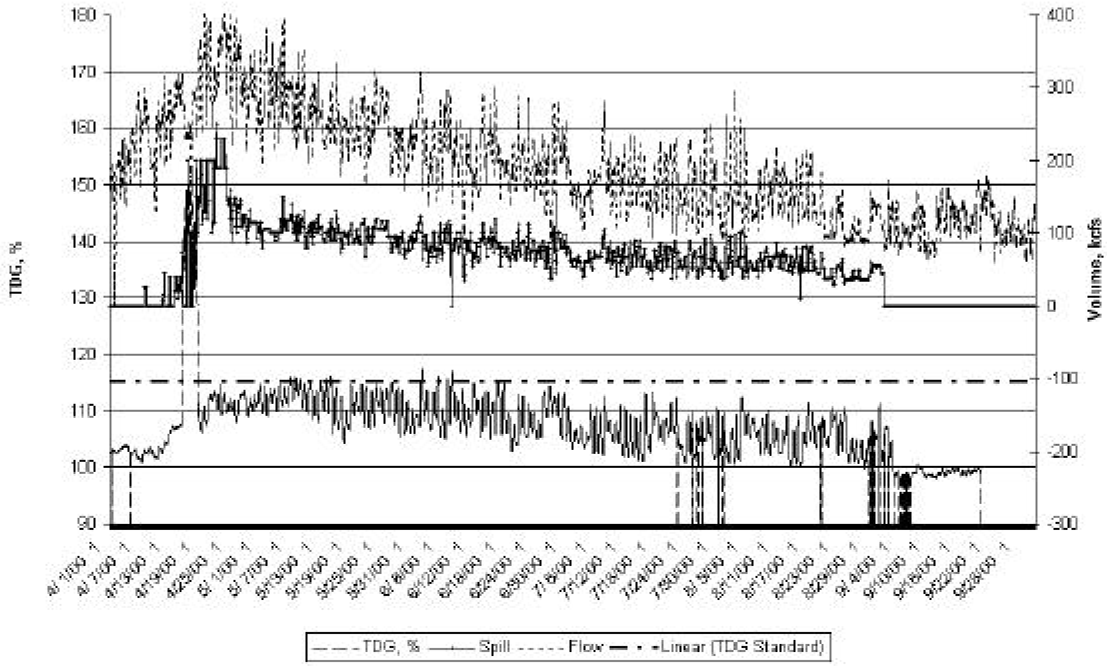
JohnDay Forebay TDG Hourly Data
1 Apr - 30 Sep, 2000



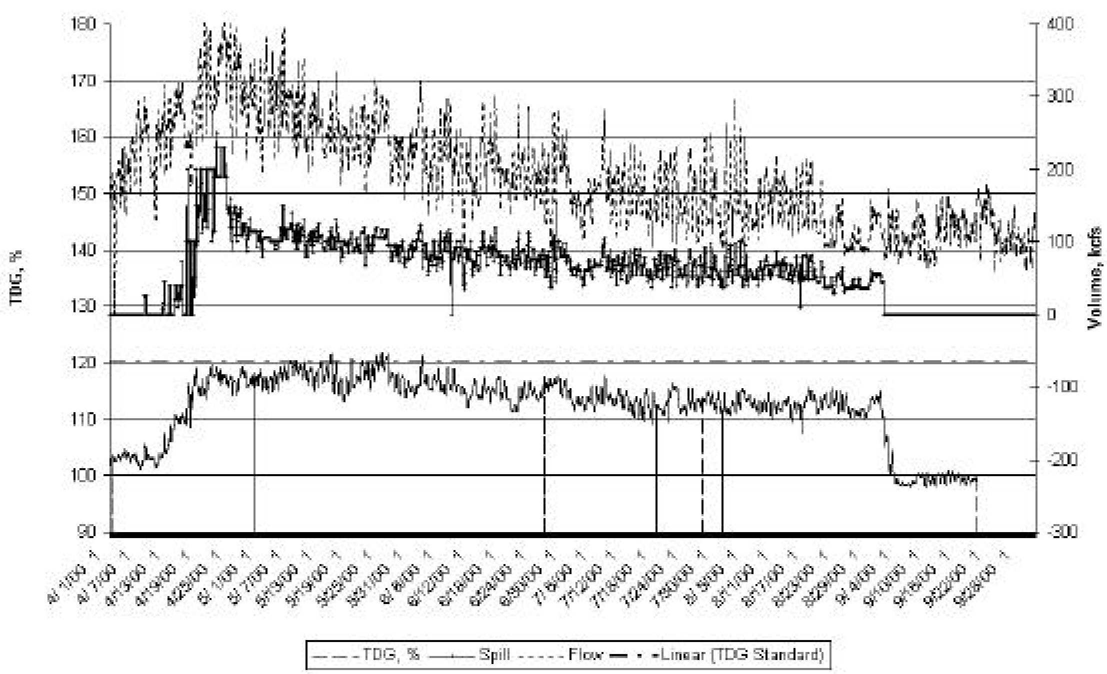
JohnDay Tailwater TDG Hourly Data
1 Apr - 30 Sep, 2000

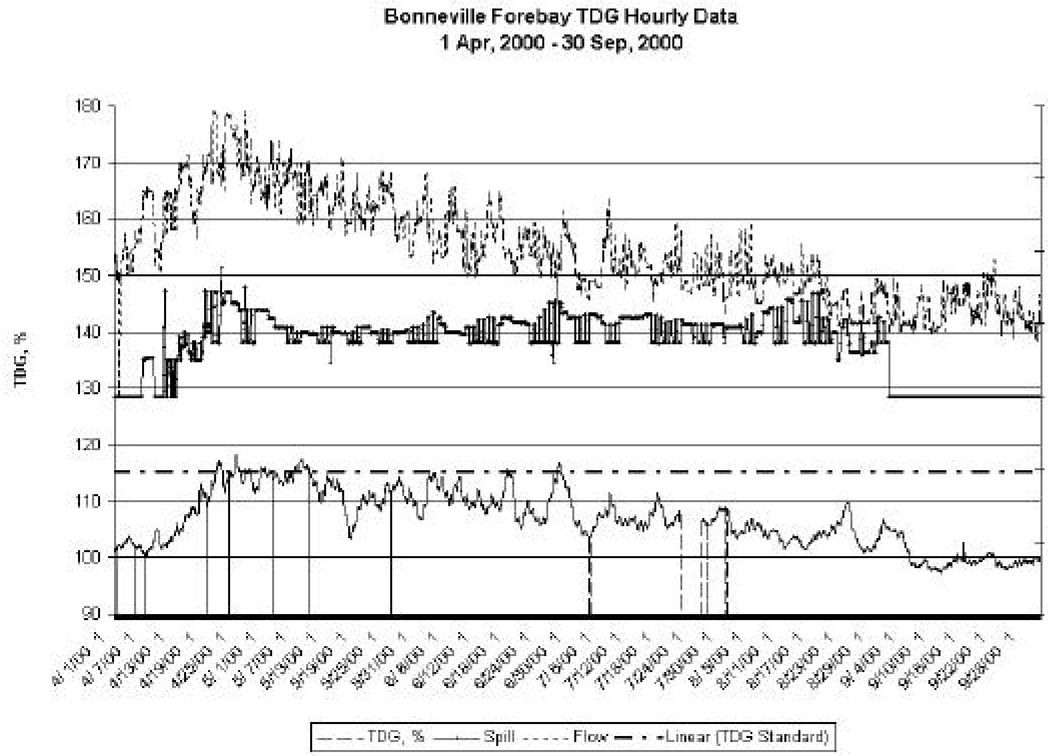


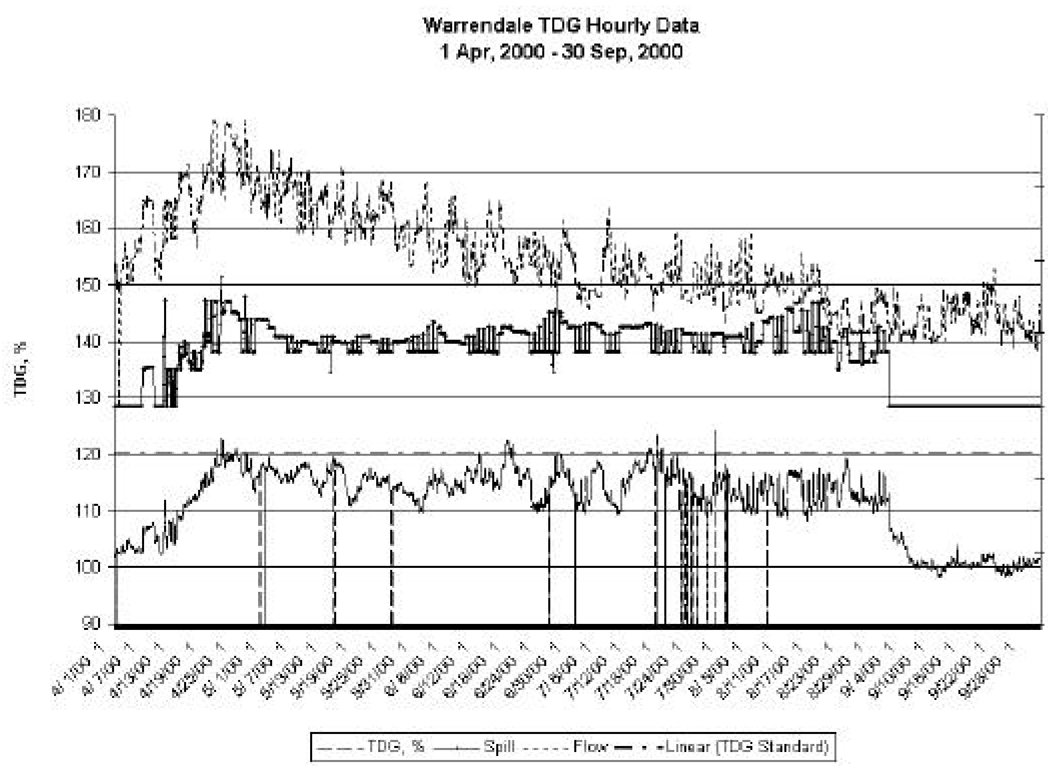
The Dalles Forebay TDG Hourly Data
1 Apr - 30 Sep, 2000



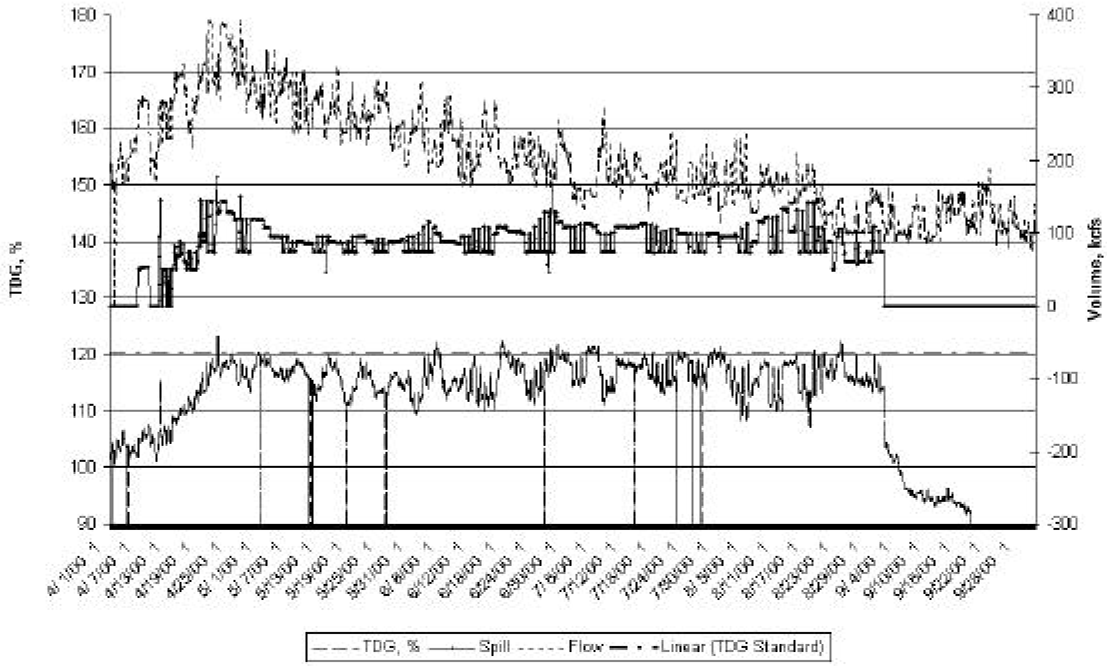
The Dalles Tailwater TDG Hourly Data
1 Apr - 30 Sep, 2000



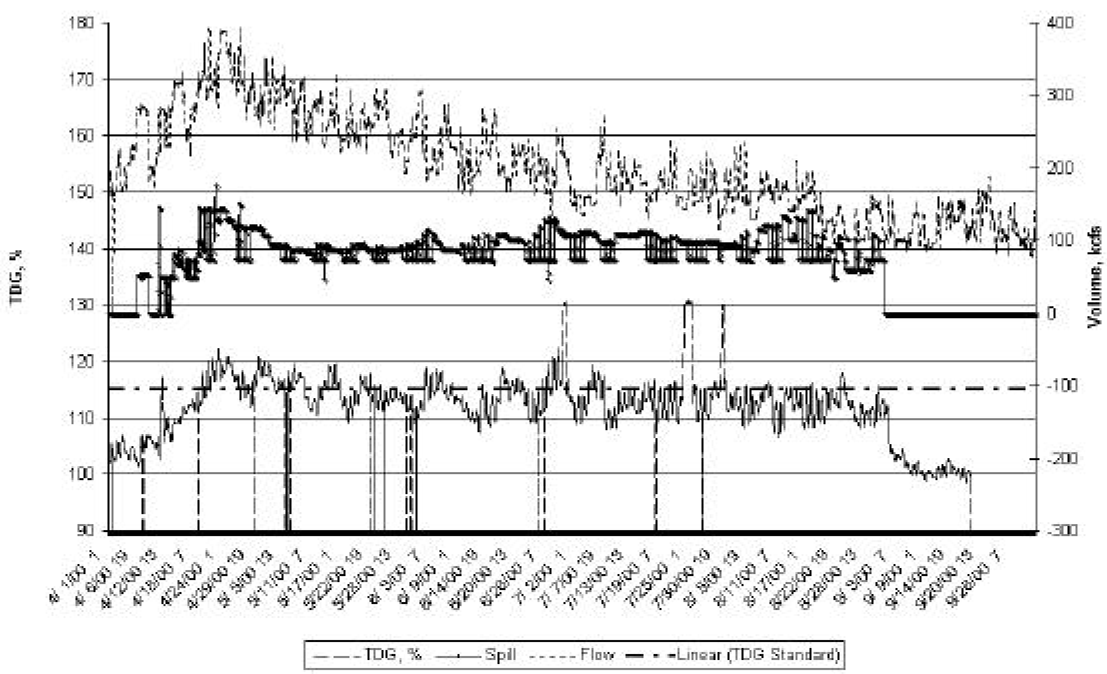

Bonneville Forebay TDG Hourly Data
1 Apr, 2000 - 30 Sep, 2000
TDG, %
Volume, kcfs
—TDG, % —Spill - - - Flow — • •Linear (TDG Standard)


Warrendale TDG Hourly Data
1 Apr, 2000 - 30 Sep, 2000
TDG, %
Volume, kcfs
—TDG, % —Spill - - - Flow — • •Linear (TDG Standard)

Skamania TDG Hourly Data
1 Apr - 30 Sep, 2000

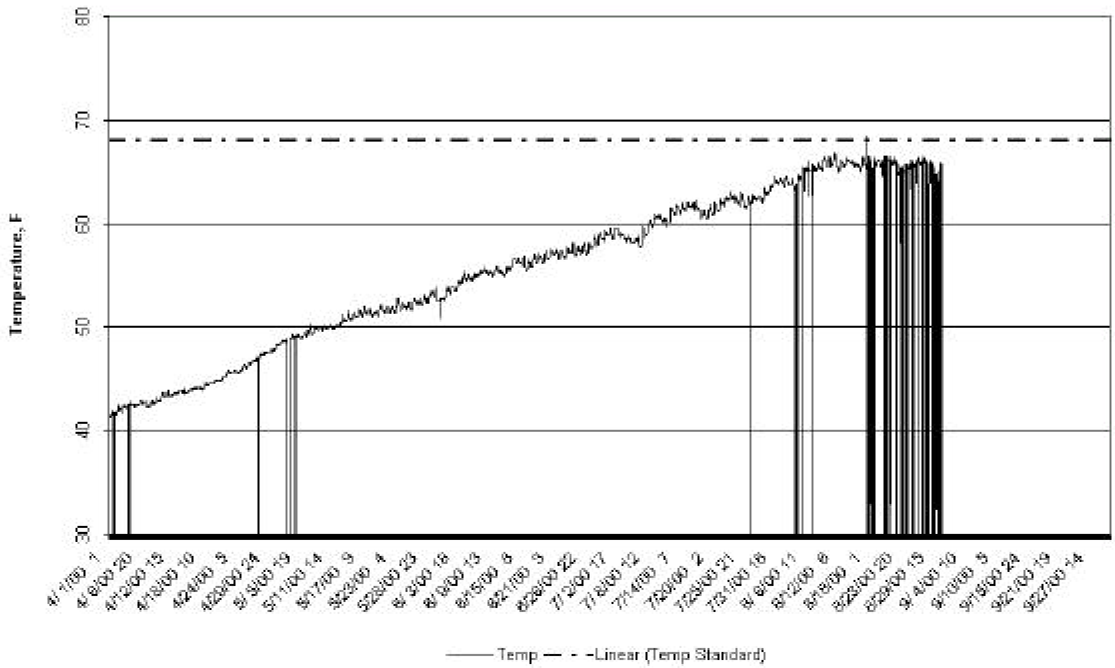


Camas/Washougal TDG Hourly Data
1 Apr - 30 Sep, 2000

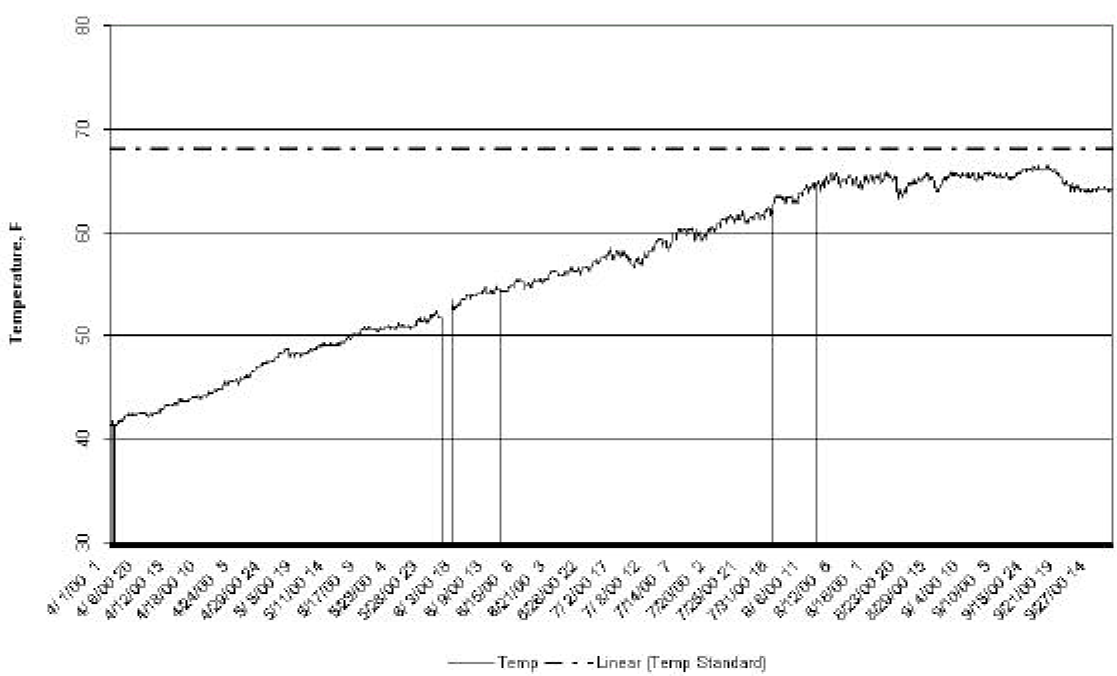


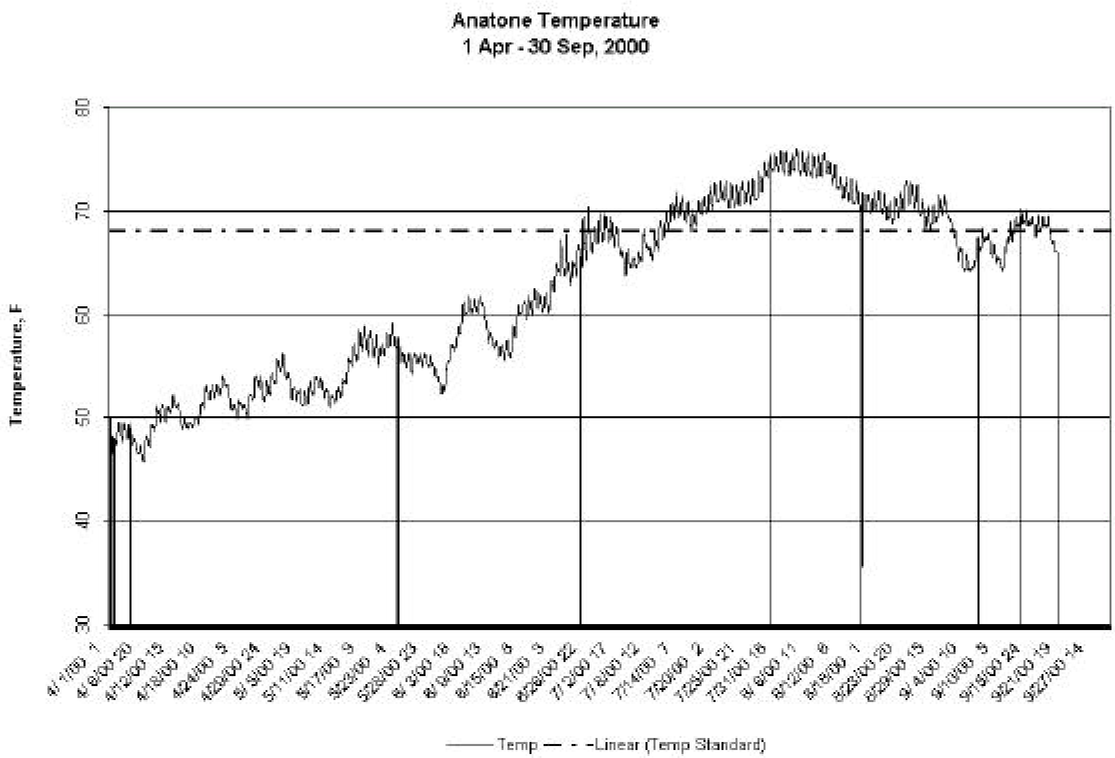
Appendix G
Temperature data graphs
Hourly data

Chief Joseph Forebay Temperature
1 Apr - 30 Sep, 2000

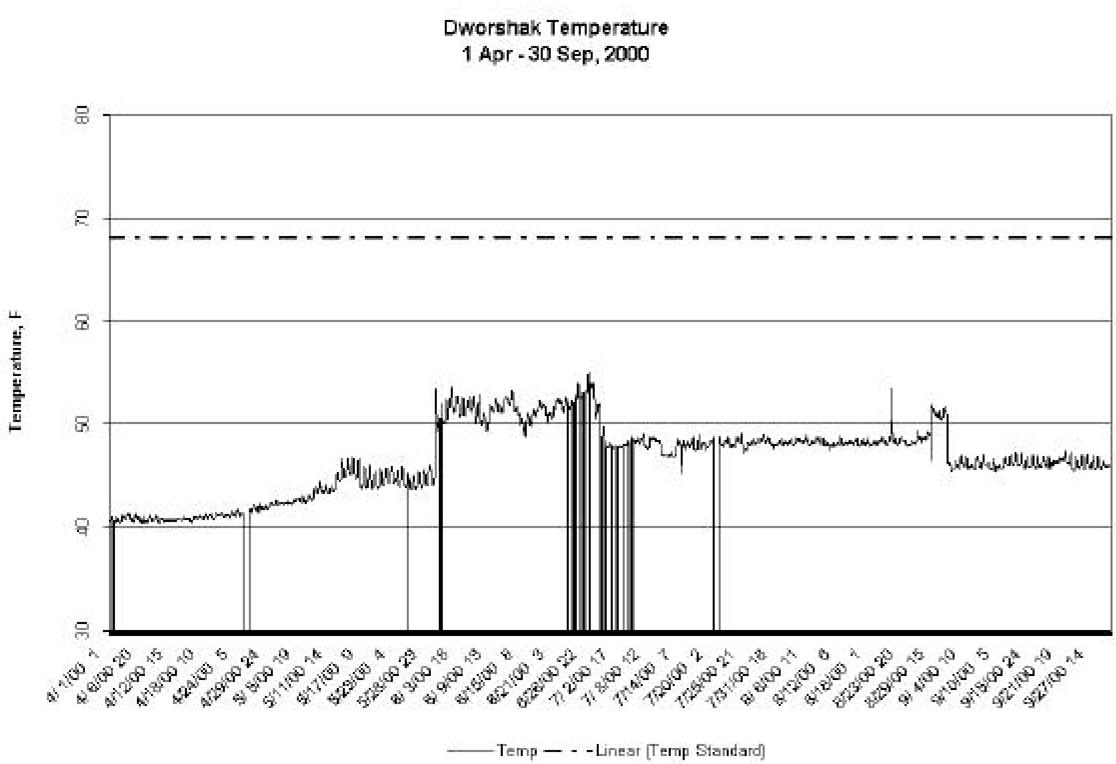


Chief Joseph Tailwater Temperature
1 Apr - 30 Sep, 2000

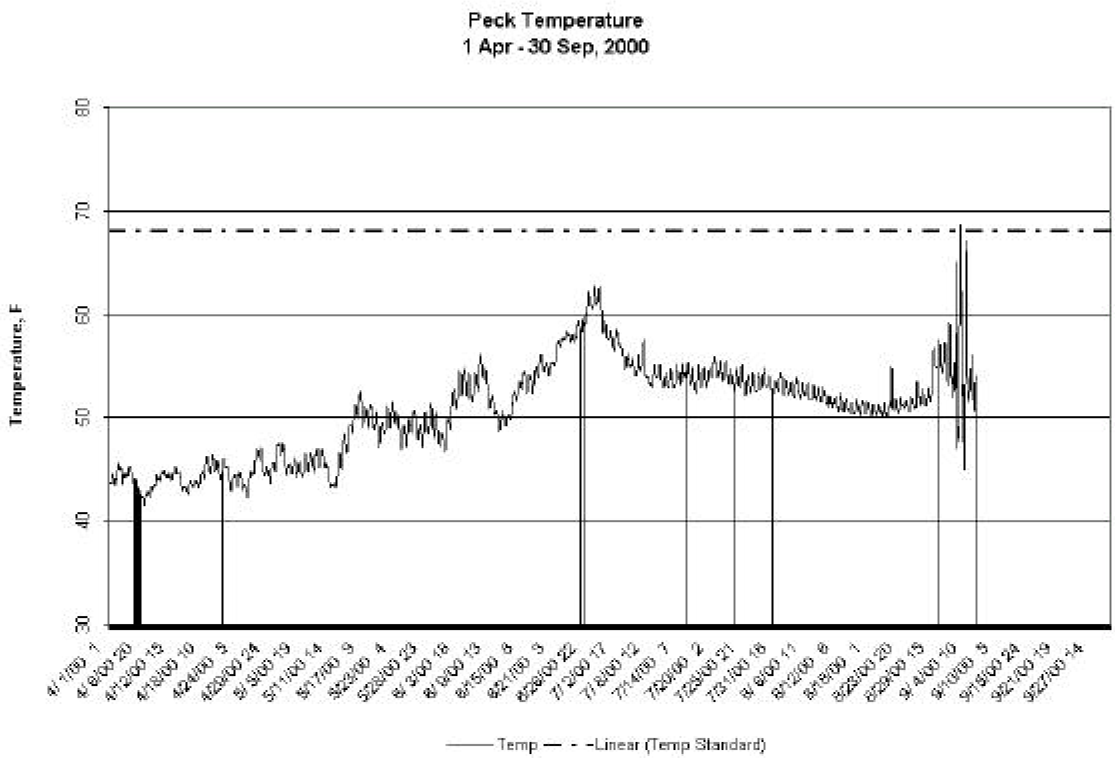


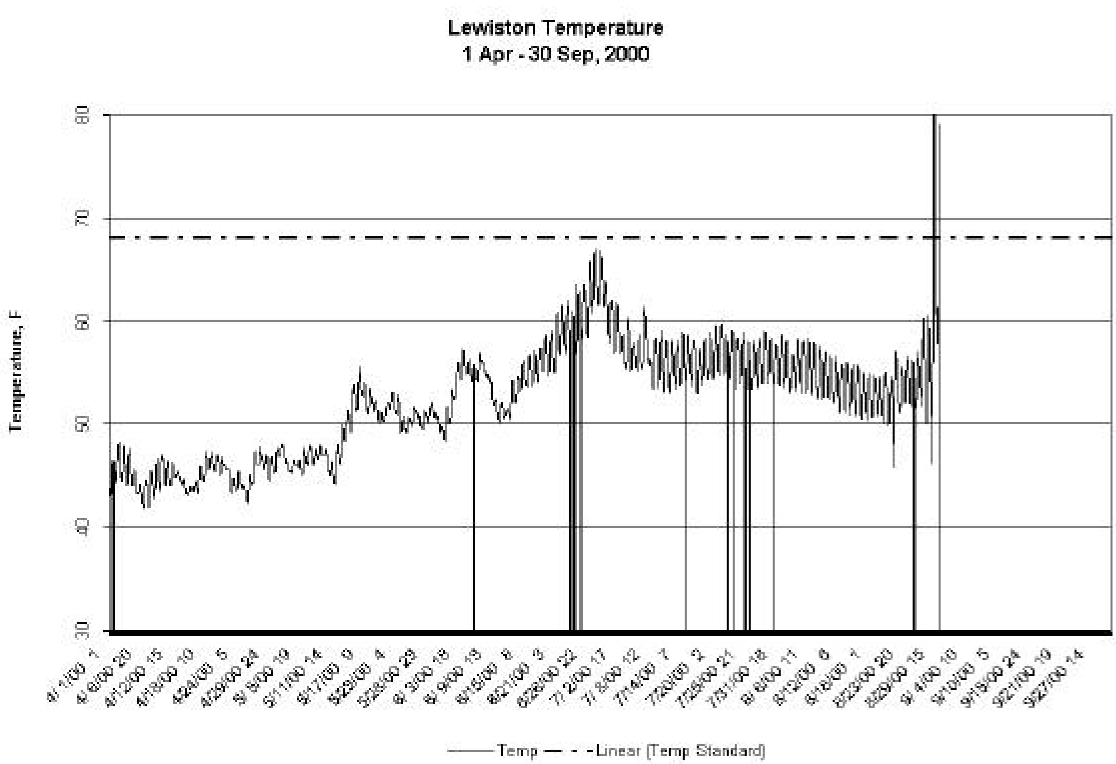


Anatone Temperature
1 Apr - 30 Sep, 2000
Temperature, F
80
70
60
50
40
30
Temp
Linear (Temp Standard)

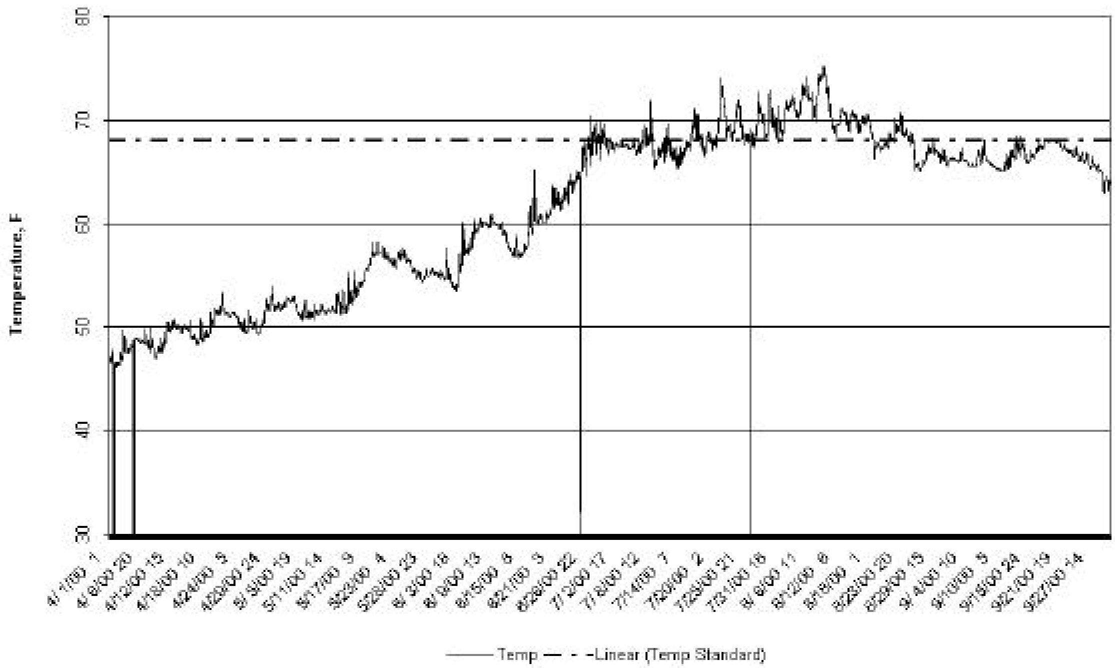


Dworshak Temperature
1 Apr - 30 Sep, 2000
Temperature, F
80
70
60
50
40
30
Temp
Linear (Temp Standard)

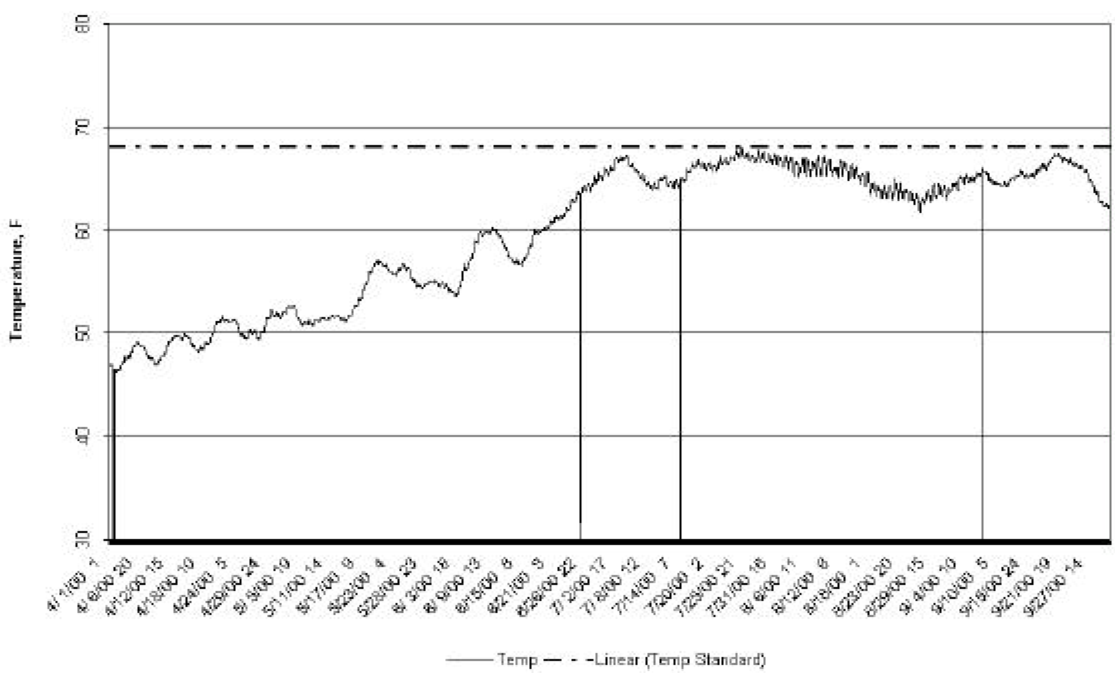

Peck Temperature
1 Apr - 30 Sep, 2000
80
70
60
50
40
30
Temperature, F
Temp
Linear (Temp Standard)


Lewiston Temperature
1 Apr - 30 Sep, 2000
80
70
60
50
40
30
Temperature, F
Temp
Linear (Temp Standard)

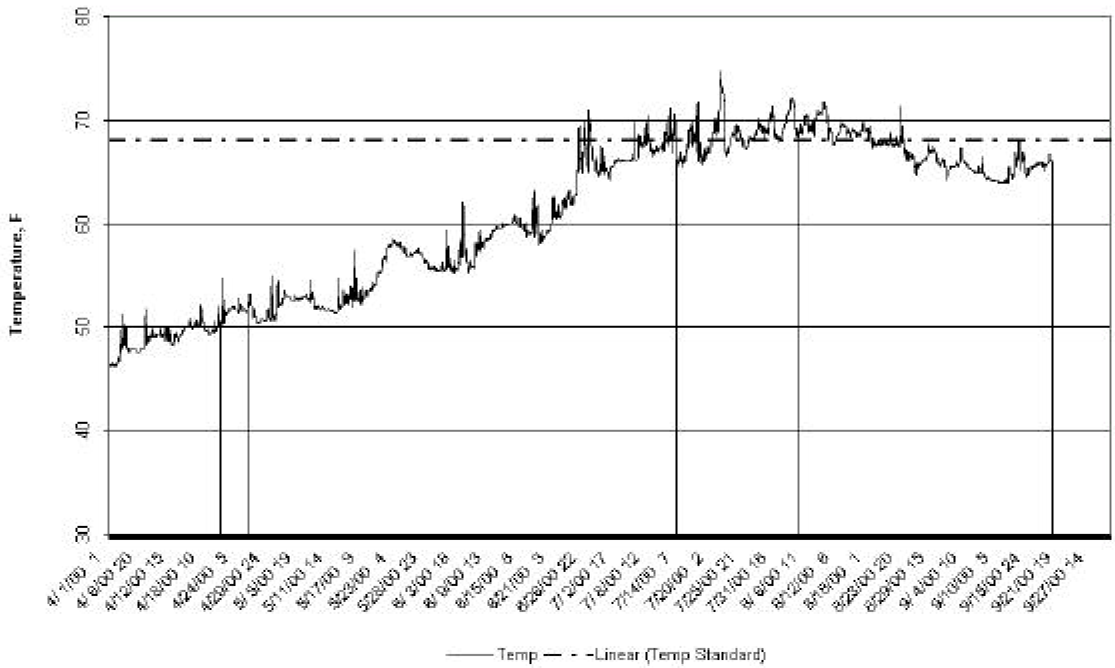
Lower Granite Forebay Temperature
1 Apr - 30 Sep, 2000



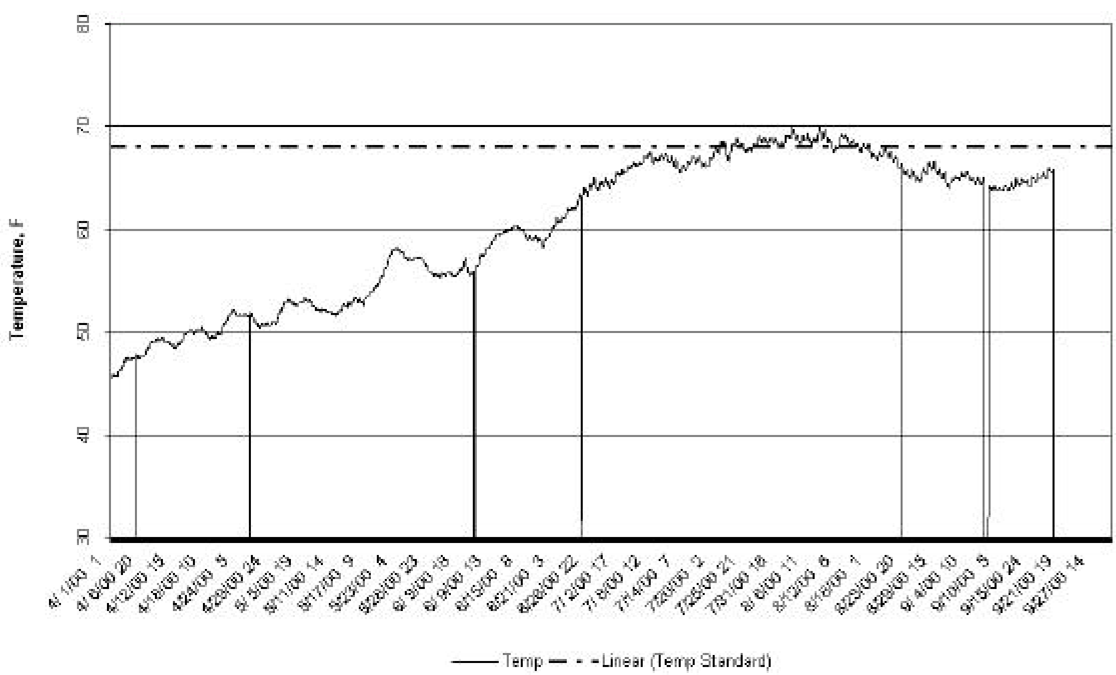
Lower Granite Tailwater Temperature
1 Apr - 30 Sep, 2000

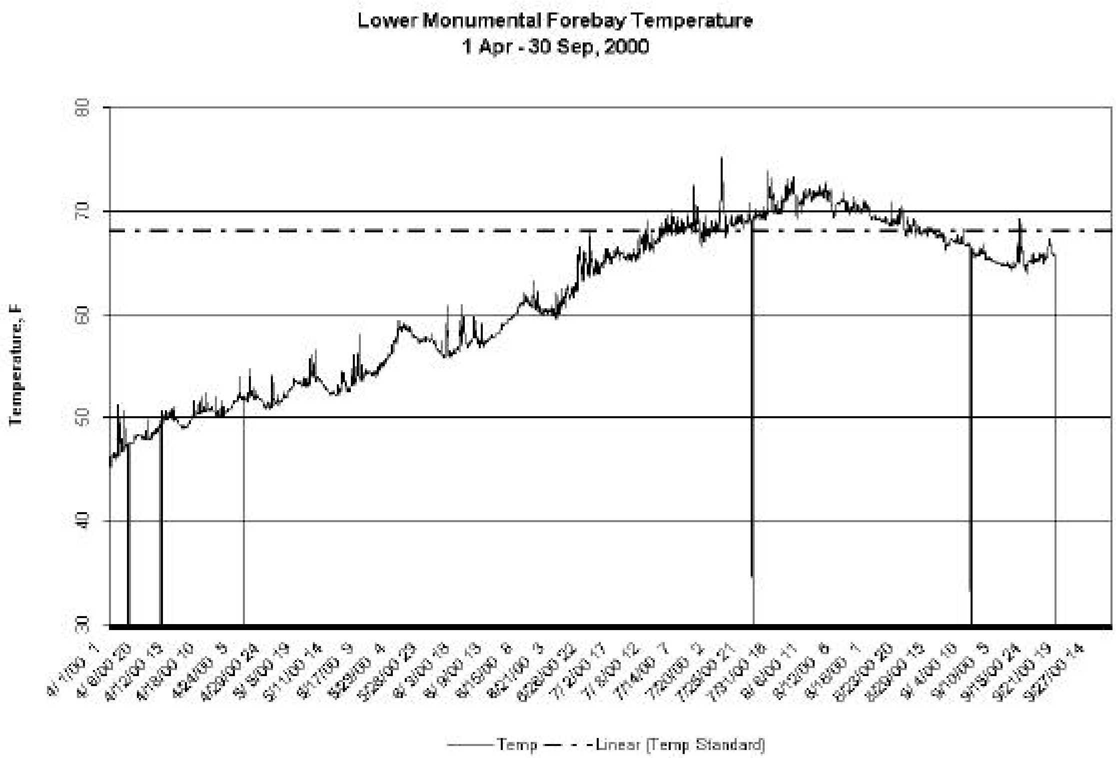


Little Goose Forebay Temperature
1 Apr - 30 Sep, 2000

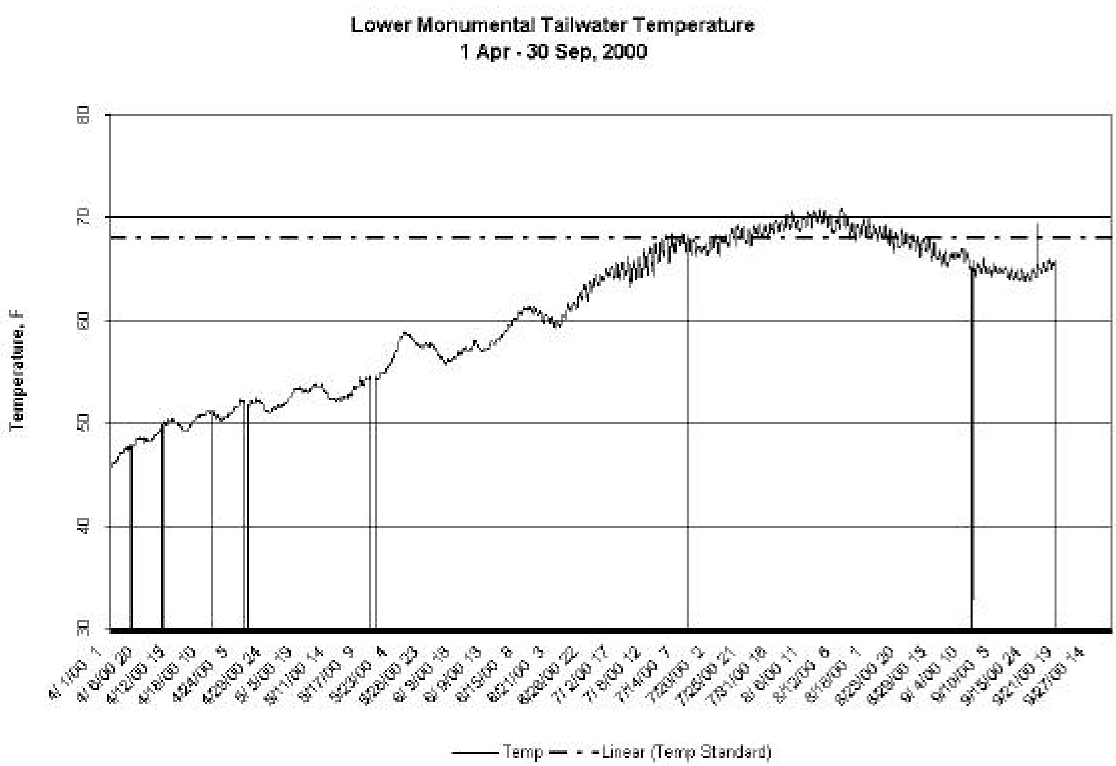


Little Goose Tailwater Temperature
1 Apr - 30 Sep, 2000

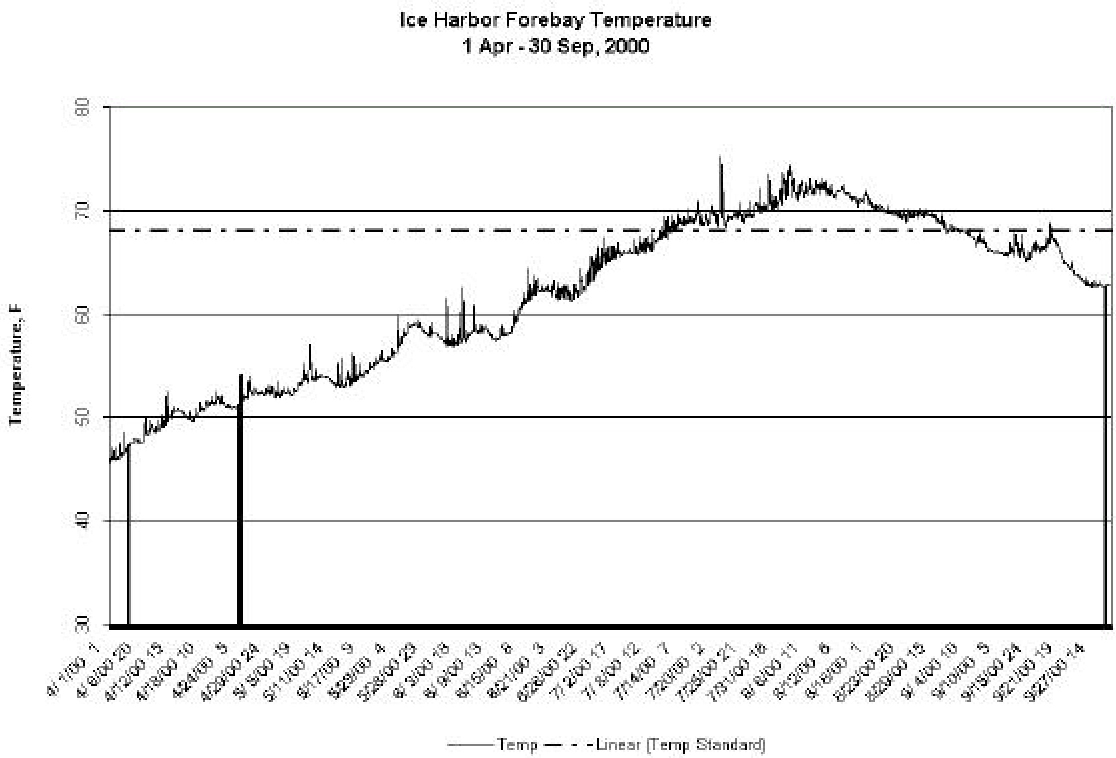


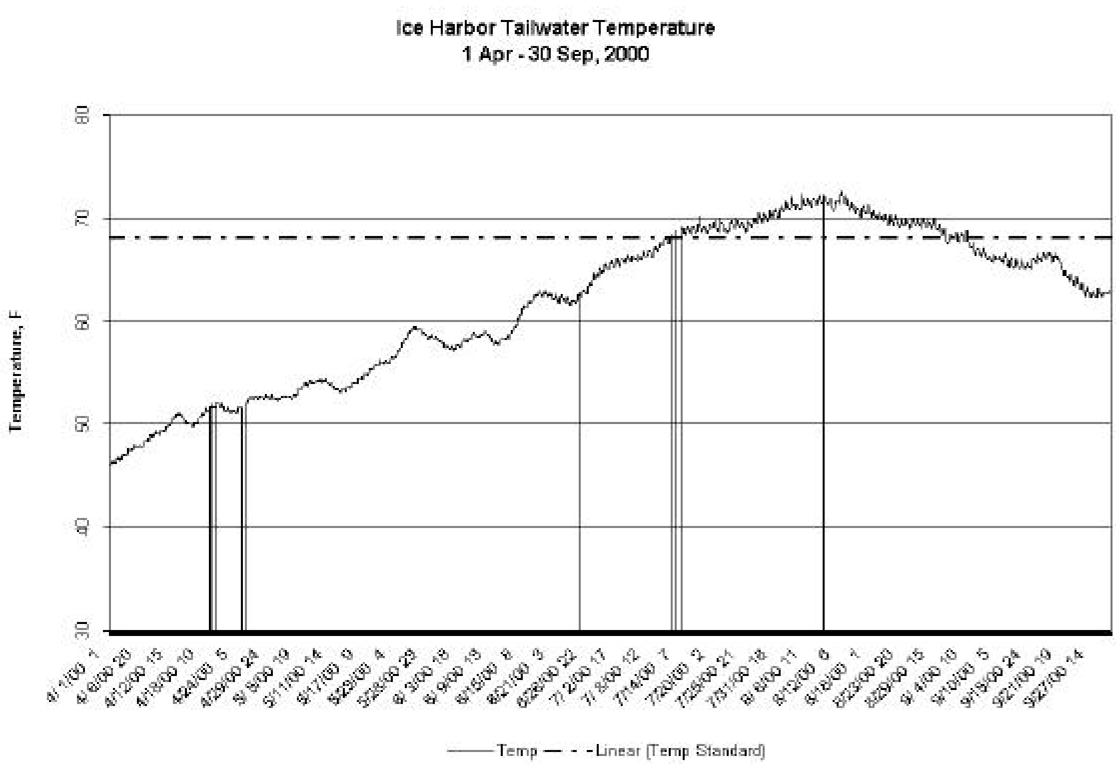


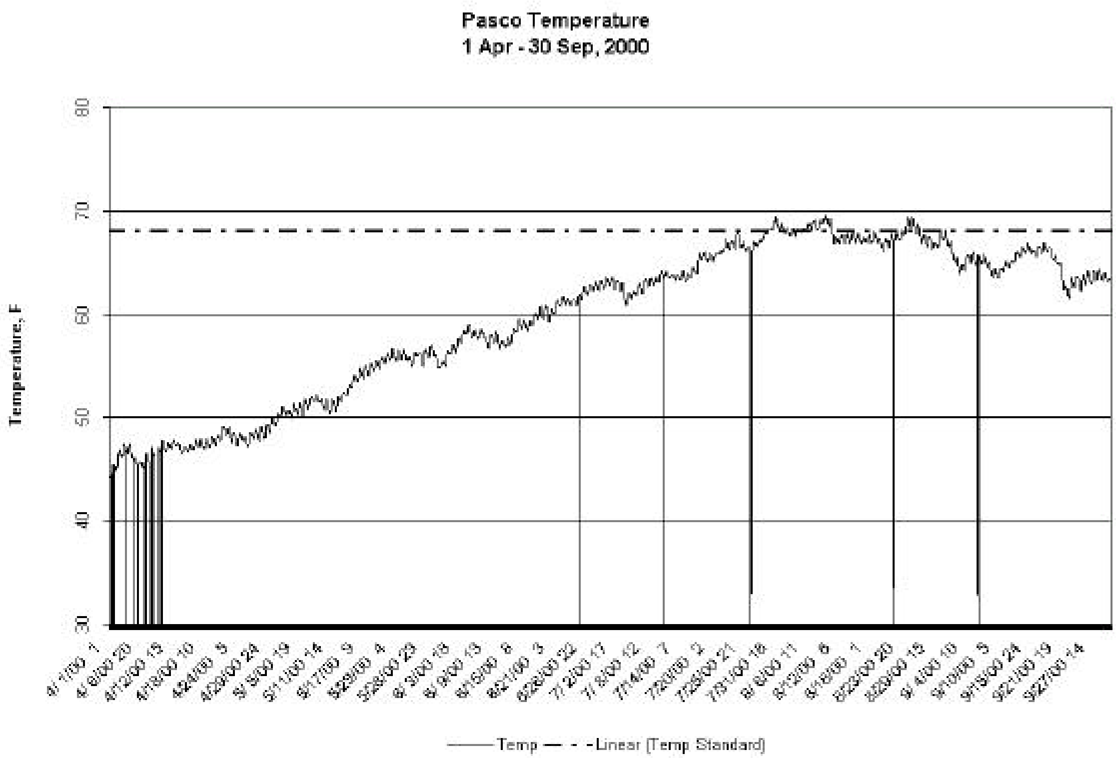
Lower Monumental Forebay Temperature
1 Apr - 30 Sep, 2000
Temperature, F
80
70
60
50
40
30
Temp
Linear (Temp Standard)

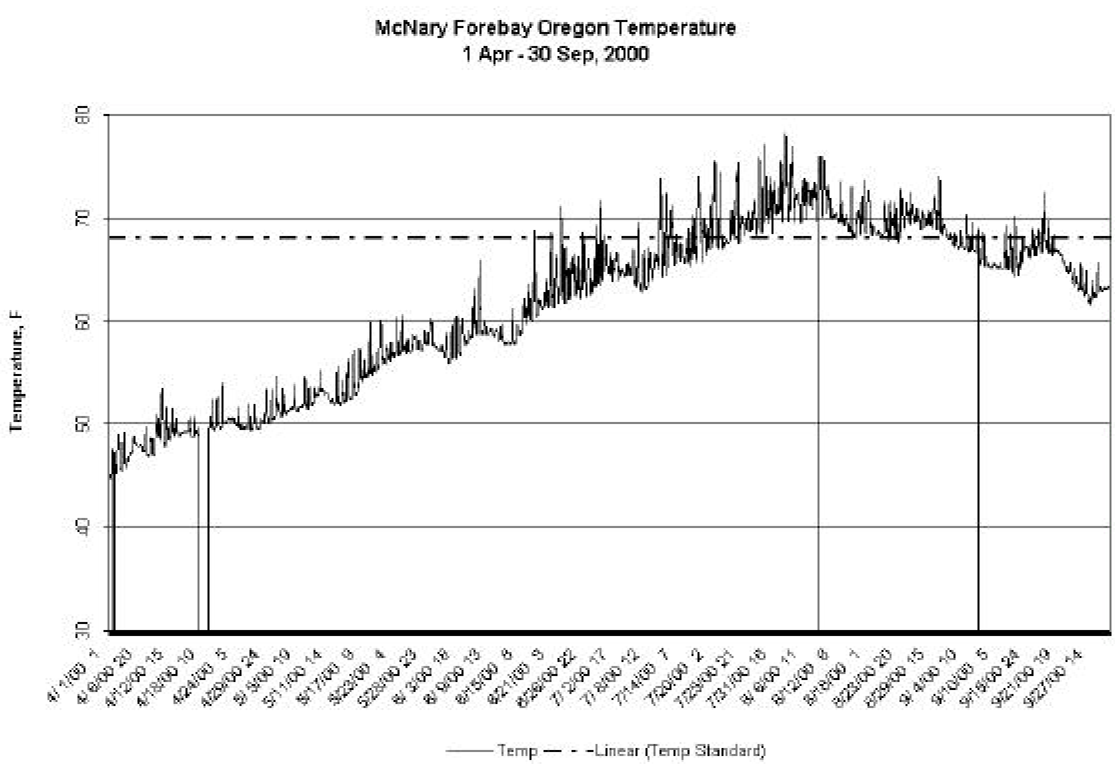


Lower Monumental Tailwater Temperature
1 Apr - 30 Sep, 2000
Temperature, F
80
70
60
50
40
30
Temp
Linear (Temp Standard)

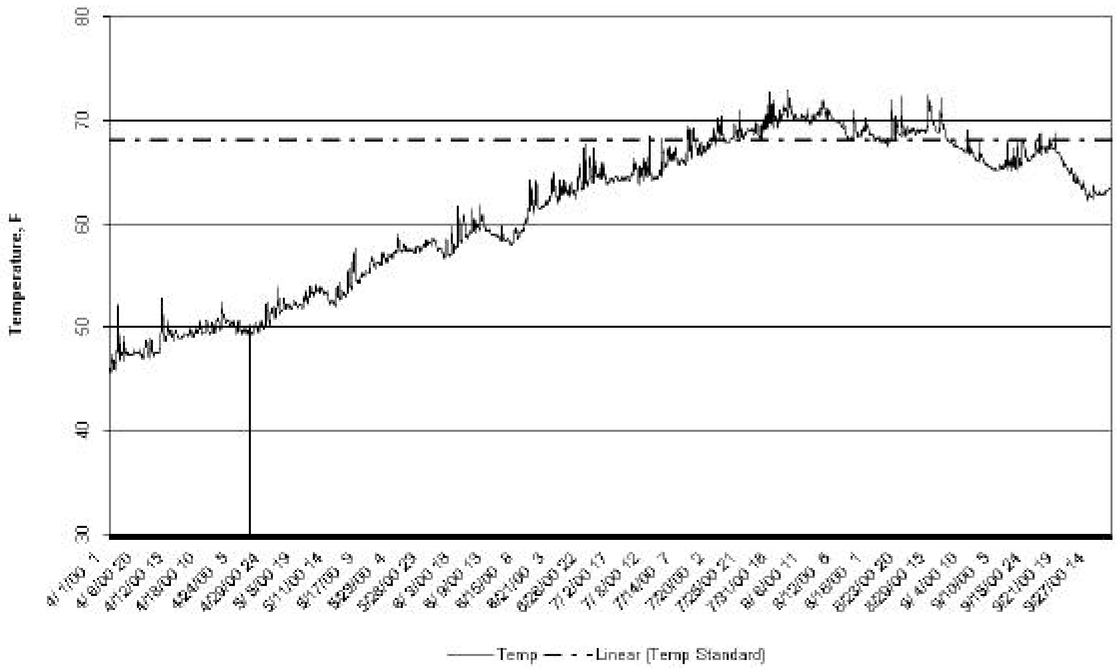

Ice Harbor Forebay Temperature
1 Apr - 30 Sep, 2000
Temperature, F
80
70
60
50
40
30
Temp
Linear (Temp Standard)


Ice Harbor Tailwater Temperature
1 Apr - 30 Sep, 2000
Temperature, F
80
70
60
50
40
30
Temp
Linear (Temp Standard)

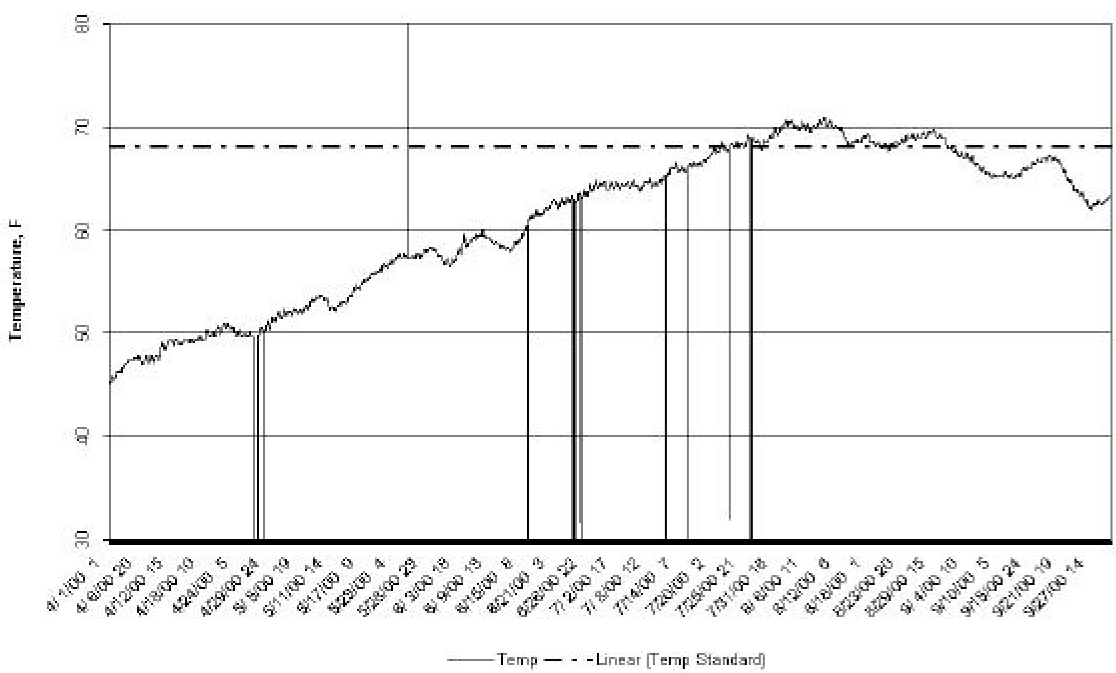

Pasco Temperature
1 Apr - 30 Sep, 2000
Temperature, F
80
70
60
50
40
30
Temp
Linear (Temp Standard)


McNary Forebay Oregon Temperature
1 Apr - 30 Sep, 2000
Temperature, F
80
70
60
50
40
30
Temp
Linear (Temp Standard)

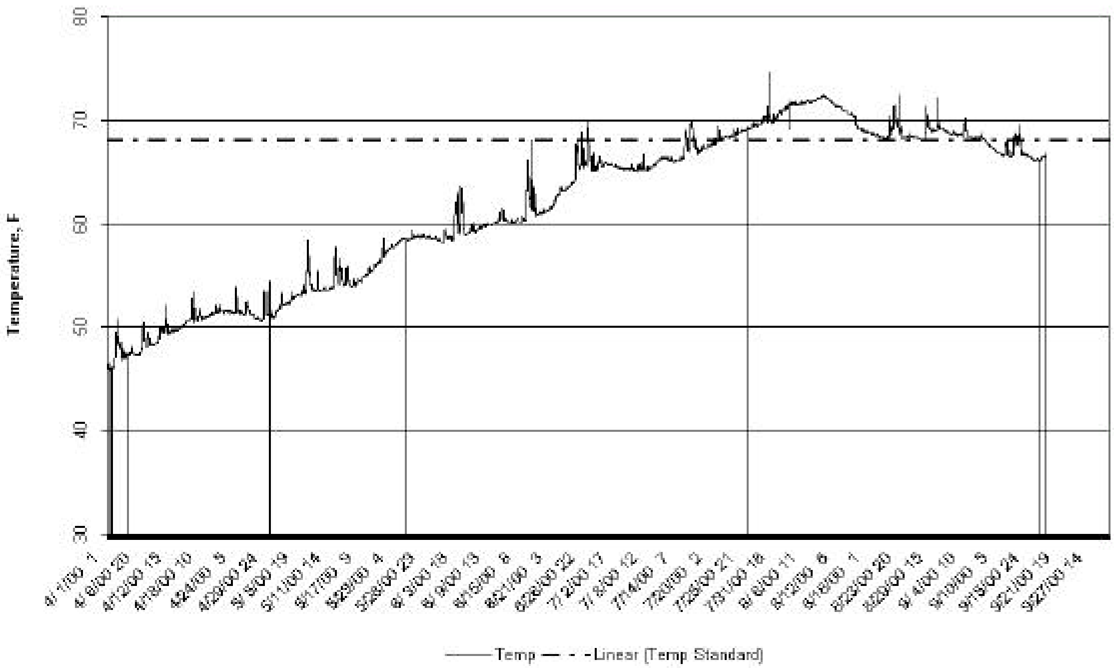
McNary Forebay Washington Temperature
1 Apr - 30 Sep, 2000



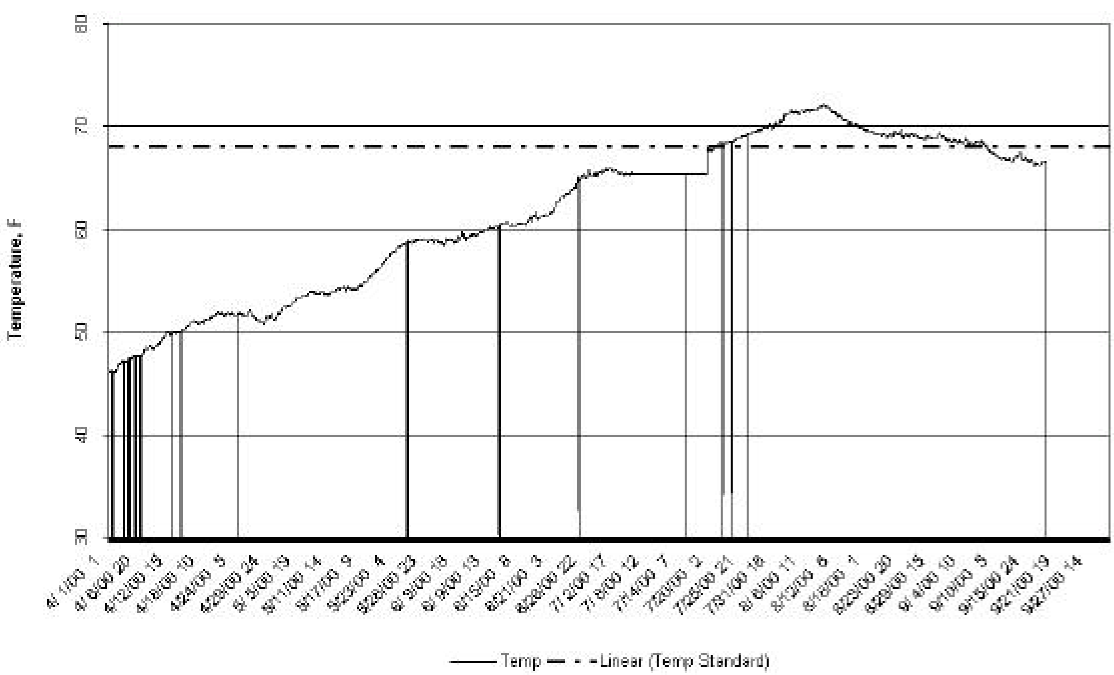
McNary Tailwater Temperature
1 Apr - 30 Sep, 2000

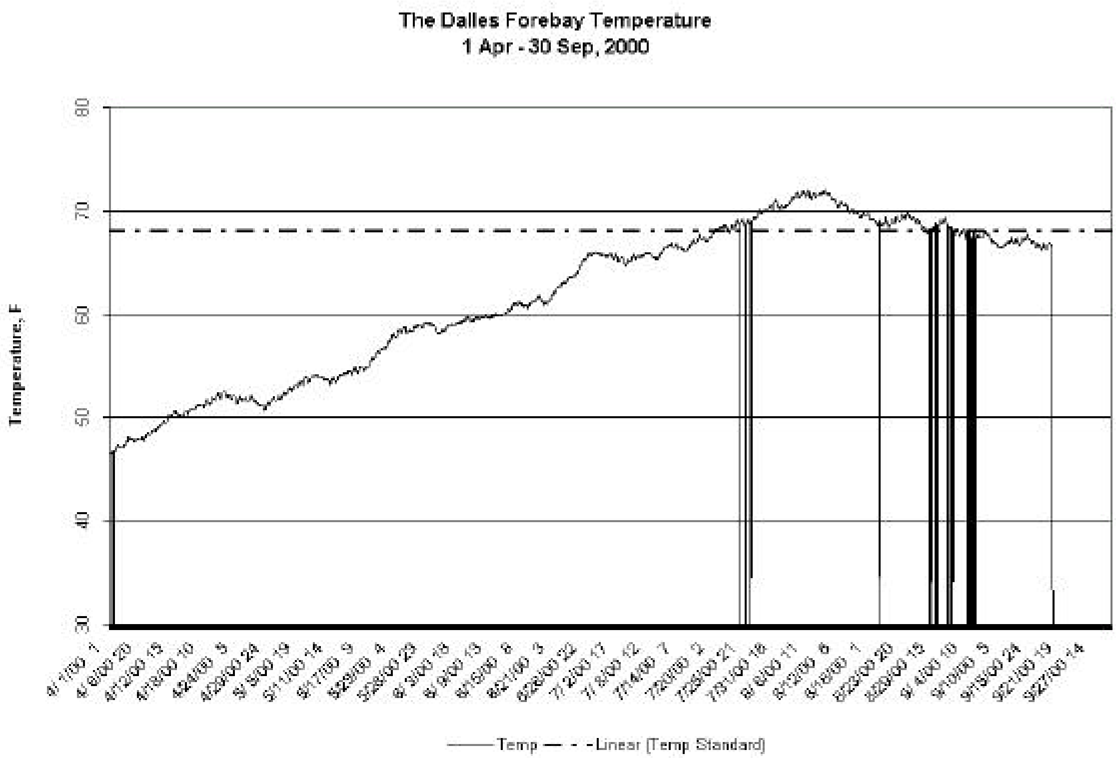


John Day Forebay Temperature
1 Apr - 30 Sep, 2000

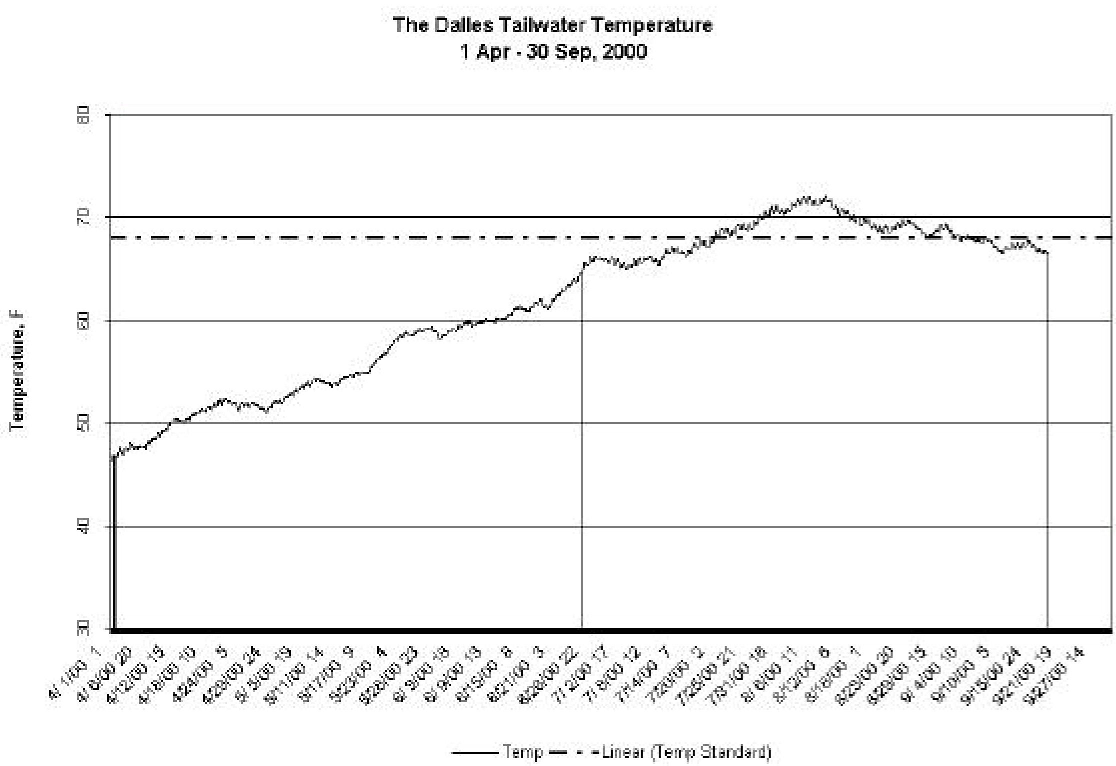


John Day Tailwater Temperature
1 Apr - 30 Sep, 2000



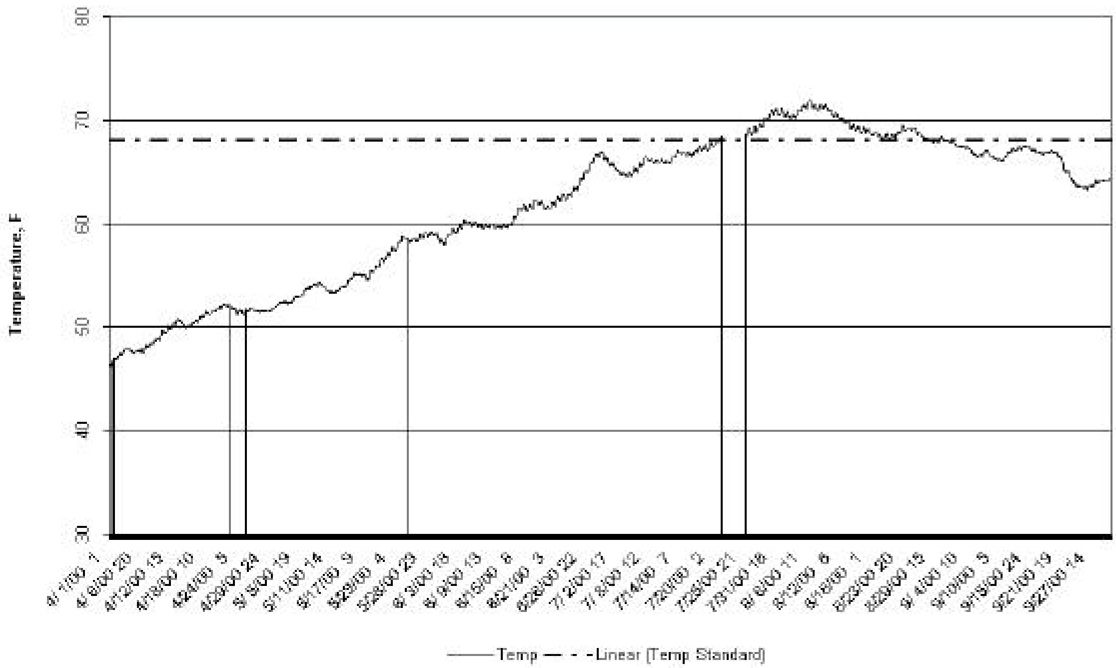


The Dalles Forebay Temperature
1 Apr - 30 Sep, 2000
Temperature, F
80
70
60
50
40
30
Temp
Linear (Temp Standard)

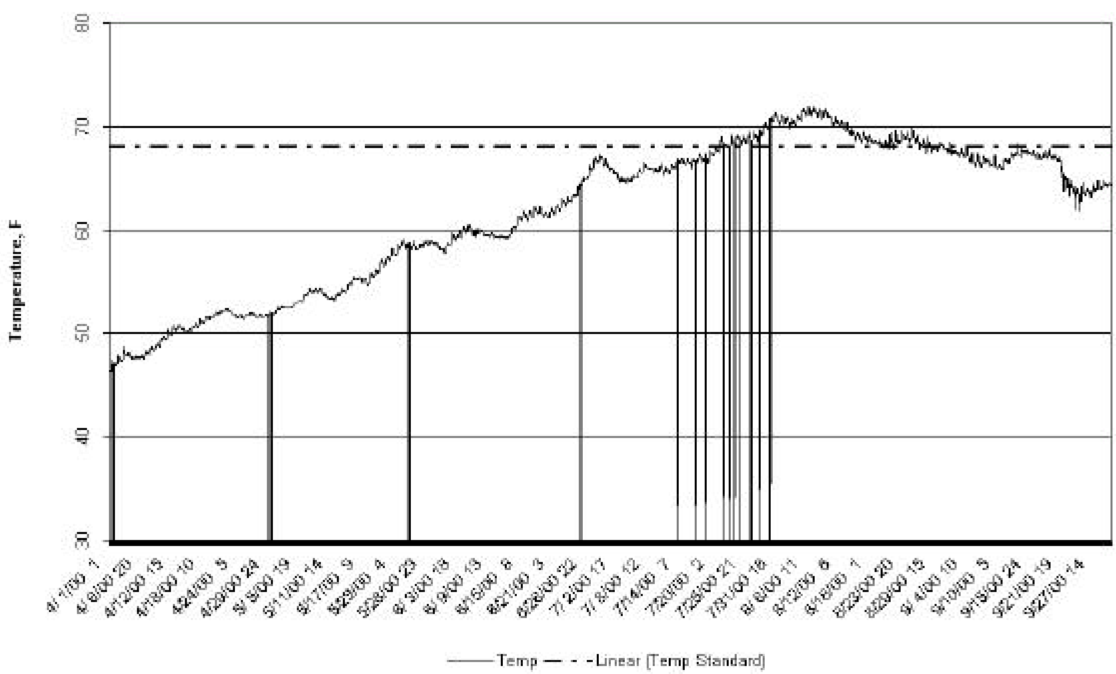


The Dalles Tailwater Temperature
1 Apr - 30 Sep, 2000
Temperature, F
80
70
60
50
40
30
Temp
Linear (Temp Standard)

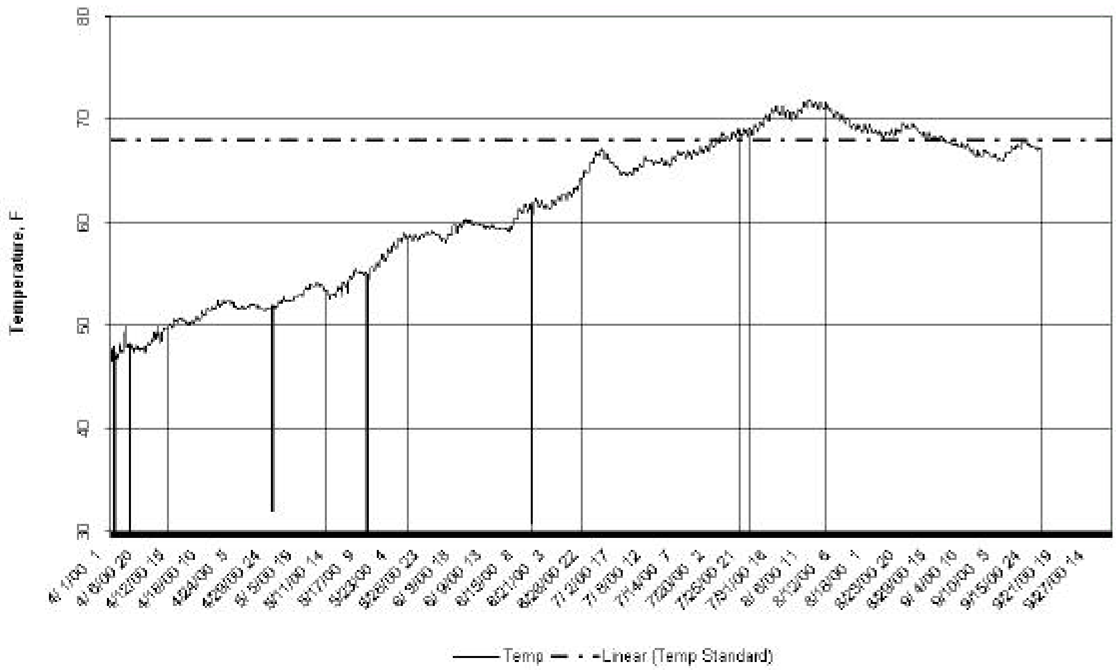
Bonneville Forebay Temperature
1 Apr - 30 Sep, 2000



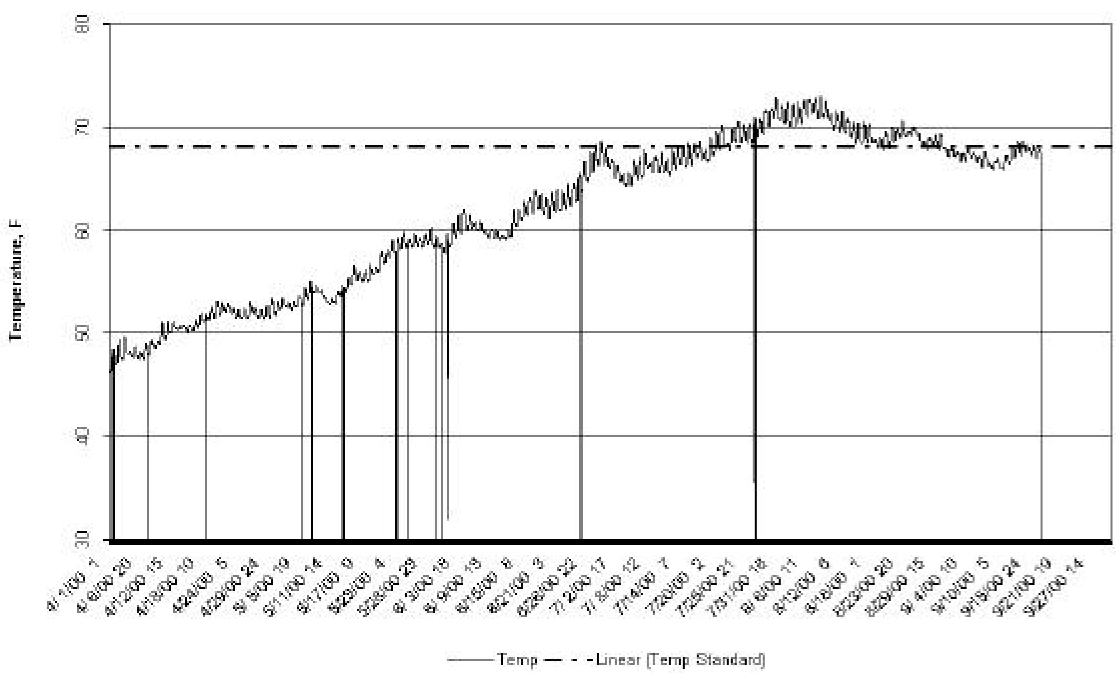
Warrendale Temperature
1 Apr - 30 Sep, 2000



Skamania Temperature
1 Apr - 30 Sep, 2000



Camas Washougal Temperature
1 Apr - 30 Sep, 2000



Appendix H
TDG decision making rationale 2000

Decision Rationale

Date *01-Jun-00*

Comments *Snake system just about as close to cap as we can get. Lower Columbia spilling below cap and forebays below 115%. Change from prolonged cool period could cause %age to increase quickly.*

Location	CurrentSpill	New Spill	Rationale
IDSW	114	114	High was 117.7%. Didn't spill to cap.
LGNW	152	152	No change. High of 120.7%; 1 hour over 120%.
LGSW	55	55	No change. High of 120.4%. 9 hours over 120%.
LMNW	48	45	High of 120.5%. Over 120% for 4 hours. 12-hour average was 119.9%.
MCPW	152	160	High was only 118.5%. 12-hour average 117.7%.
TDDO	123	128	High of 116.0%. Didn't spill to cap, but it was close.
WRNO	100	110	High of 111.9% at Camas, which was a drop from yesterday's 114.3%

Date *02-Jun-00*

Comments *Lower Snake gas levels in the forebays and tailweaters are running near their gas cap limits. With warming weather beginning, the caps will have to be looked at closely over the weekend. Also, The Dalles forebay is over the 115% level for 8 hours and*

Location	CurrentSpill	New Spill	Rationale
SKAW	110	115	Max was 118.1%. Camas at 113%
LGSW	55	50	Max of 121.1%; over the 120% level for 10 hours. LMN forebay over 115% cap for 5 hours.
LMNW	45	40	Max of 120.9%; over 120% level for 4 hours. IHR forebay was over 115% for 10 hours.
JHAW	172	170	Max of 120.4% ; over 120% level for 1 hour. TDA forebay over 115% for 8 hours.TDA did not spill to cap.
WRNO	110	115	Max was 116.1%. Camas at 113%. Could go 10 KCFS but the weather is warming.

Date *03-Jun-00*

Comments *Snake needs adjustment but the lower Columbia doing well*

Location	CurrentSpill	New Spill	Rationale
SKAW	115	110	Max was 120.2% for 2 hourd; CWMW was over 115% for 11 hours.
LMNW	40	35	Max was 119.9%; IHR was over 115% for 22 hours.
LGNW	62	58	Max was 121.8%; over 120% for 10 hours.
LGSW	50	45	Max was 119.7%; LMN was over 115% for 12 hours.

Date *04-Jun-00*

Comments *IHR heating up and increasing in gas level. Camas also reating up and increasing in gas level. JDA di not spill to cap.*

Location	CurrentSpill	New Spill	Rationale
LGSW	45	42	Max is 119.2% but LMN is over 115% for 8 hours.
LMNW	35	30	Max is 118.1% but IHR is over 115% for 22 hours.
JHAW	170	170	No change. Max is 118.8% and TDA max only 113.3%. However, JDA did not spill to cap of 170 kcfs. It only went to 162.

Date *05-Jun-00*

Comments *Increased temperature in the region is apparent in the increasing TDG levels through out the system. Cooler weather is expected for the next few days then a gradual increase to region norms by the weekend.*

Location	CurrentSpill	New Spill	Rationale
LGSW	42	37	Reduction to bring down LMN forebay
LMNW	30	25	Reduction to bring down IHR forebay.
IDSW	114	90	Reduce spill to approximate 100 % of flow. At 100% flow MCQW forebay over 115 12 hour average for 6 hours.
JHAW	170	170	No change at JDA even though TDA forebay over 115 because of spill test pattern. JDA will be spilling 0 for 12 hours.
CWMW	100	90	Reduction at BON to reduce SKAW and Camas TDG. Camas TDG over 115 for 15 hours. BON on continuous spill for the next 6 days.

Date *06-Jun-00*

Comments *Weather conditions appear stable for the next few days. Operating conditions at LWG and Lower Snake projects may change early next week due to no more use of Surface Bypass Collector at LWG and the beginning of fish barging.*

Location	*CurrentSpill*	*New Spill*	*Rationale*
CWMW	90	90	No change. Wait one more day to see if yesterdays change at BON was enough to reduce TDG at Camas.
LGSW	37	35	Reduce spill to decrease TDG in LMN forebay. LMN forebay over 115 for 12 hours with a high of 117.3
TDDO	128	128	Looked at increasing at TDA since the Tailwater TDG is only up to 116.6% Decided not to since the project did not spill to the current cap.
LMNW	25	25	No change. Considered a change since IHR forebay is over 115 for 20 hours with a high of 119.2. Decided no change since it appears that the decreased spill at LMN is bringing the TDG down below 115 based on the check_spill information.

Date *08-Jun-00*

Comments *System appears fairly stable with slight upward trend.*

Location	*CurrentSpill*	*New Spill*	*Rationale*
LGSW	35	32	LMN forebay 12 hour average over 115 for at least 5 hours.
IDSW	90	85	MCN forebay Oregon side 12 hour average over 115 for 8 hours.
JHAW	170	160	TDA forebay over 12 hour average for 6 plus hours. Don't have current information from Priest Rapids to clarify the picture. Make change here tomorrow as spill schedule changes per the test pattern.
TDDO	128	128	BON forebay is at 114 in the hourly data and trending up rapidly. No change. Watch tomorrow.
WRNO	90	85	Camas TDG over 115 for 10 hours with the 12 hour average over 115 for 8 plus hours. Make change here tomorrow due to spill schedule change.
LMNW	25	25	No change. LMNW is only at 117 but IHR forebay is at 114.5%

Date *09-Jun-00*

Comments *Received comments from Jim Ceballos of NMFS. He is concrned that we could spill more on the Snake River projects (LWG, LGS, LMN, an MCN) as mentioned in a TMT call.*
We are reviewing our calculations and decision making criteria.

Location	CurrentSpill	New Spill	Rationale
IDSW	85	90	Increase. MCN forebay 12 hour avg only 113.3%, finally moved below 115%
CWMW	85	95	Camas 12 hr avg = 113.7% Project will be only spilling 75KCFS during the day according to the test schedule. Increase cap slightly (one day) in anticipation of the decreased gas levels during this test condition.
TDDO	128	128	No change. Low gas levels but the project is currently not spilling to the cap.
MCPW	160	160	No change. 12 hour avg reached 119.9% Good trend over last three days , 12 hour avg holding between 119 and 120%
LMNW	25	30	Increase. IHR forebay 12 hour avg only reached 113.9%
LGSW	32	32	The adjustment down yesterday brought the LMN forebay into compliance (12 hour avg = 114.6) No change here even though tailwater is only 114.5.
LGNW	58	60	12 hour avg dropped below 119%.
JHAW	160	160	No change. Not reaching cap often. When they did at 170KCFS the TDA forebay has been over 115%

Date *10-Jun-00*

Comments *TDG is the system dropping off.*

Location	CurrentSpill	New Spill	Rationale
SKAW	0	0	CWMW was 113.9% but WRNO was 118.1% and SKAW was 116.9%. Wasn't sure how much dissapation would occur, therefore, no change.
LGSW	32	42	Max was only 115.1% LMN forebay only 112.1%
LMNW	30	40	Max was only 115.9%. IHR forbay only 112.5%
IDSW	90	100	Max was only 116.7% Spilled to max of 90 kcfs for 1 hour, therefore, go to 100 kcfs even if it only gets there for 1 hour.
MCPW	0	0	Didn't spill to cap.
JHAW	0	0	Didn't spill to cap

TDDO	0	0	Didn't spill to cap.

Date *11-Jun-00*

Comments *TDG in the system still dropping.*

Location	CurrentSpill	New Spill	Rationale
SKAW	95	105	Max was 117.6%. CWMN was only 112.6%; it dropped from yesterday
LMNW	42	50	Max was 117.8%. IHR was only 109.8%.
MCPW	160	170	Max was 118.5%. JDA was only 107.8%.
WRNO	95	105	Max was 117.2%. It dropped since yesterday.
LGSW	42	47	Max was 118.0%. LMN was only 109.9%

Date *12-Jun-00*

Comments *Cool, wet weather presists. System TDG getting close to operating goals of 115% and 120%.*

Location	CurrentSpill	New Spill	Rationale
LGNW	60	62	Max was 119.7% 12-hour average was 118.8%
TDDO	123	123	No change because it didn't spill to the cap. High of 116.1%
LMNW	45	48	High of 119.1%.
JHAW	172	172	No change because it didn't sdpill to cap. High of 118.9%.
LGSW	53	55	Max was 120.2%; over 120% for 2-hours and LMN over 115% for 4 hours.
IDSW	109	114	High of 118.6%.
WRNO	95	100	High of 114.3% at Camas.
MCPW	150	152	High of 119.4%.

Date *13-Jun-00*

Comments *Low runoff on the Snake and lower Columbia causes several of the Corps projects not to spill to the caps.*

Location	CurrentSpill	New Spill	Rationale
LGSW	0	0	No change. Project didn't spill to cap.
WRNO	105	110	Max was 120.0%. 12-hour high was 118.48%. CWMW max was only 111.6%; 12-hour high was 110.82%
TDDO	0	0	Didn't spill to cap.

JHAW	0	0	Didn't spill to cap.
MCPW	170	175	Max was 119.2%. 12-hour high was 118.85%. JDA max was only 118.85%.
IDSW	0	0	No change. Project didn't spill to cap.
LMNW	0	0	No change. Project didn't spill to cap.
SKAW	105	110	Max was 118.9%.

Date *14-Jun-00*

Comments *Expected dramatic increase in temperature is predicted to be reflected in increasing gas levels tomorrow. Make changes as BON and JDA tomorrow in anticipation of the changed spill requirements specified in the spill test schedule for these sights.*

Location	***CurrentSpill***	***New Spill***	***Rationale***
LGSW	47	50	Average of 12 highest readings in 24 hours = 118.5%
MCPW	175	175	Change at MCN yesterday appears to have been appropriate for conditions. High 12 in 24 avg = 119.5%
JDA	160	160	No change. Not spilling to cap.
CWMW	110	110	Change at BON yesterday appears to have been appropriate for conditions.
LMNW	50	42	Average of 12 highest readings in 24 hours = 121.3%
TDA	128	128	No change. Not spilling to cap.

Date *15-Jun-00*

Comments

Location	***CurrentSpill***	***New Spill***	***Rationale***
JHAW	160	160	Project did not spill to the gas cap for a long period of time. When the gas cap was reached, the TDG levels appeared to be very near 120%
LGSW	50	52	High 12 in 24 avg = 118.6%
TDDO	128	128	Did not spill to gas cap.
IDSW	100	105	Spilled to cap. Highest hourly TDG = 118.3% No exceedance at MCN.
LMNW	42	45	Yesterday ruced from 50 to 42. Reduction appears to have been to drastic for given conditions.
CWMW	110	100	TDG levels are acceptable. Decrease gas cap in anticipation of daytime operation change starting tomorrow according to the test pattern.

Date *16-Jun-00*

Comments *Warmer weather expected impacts the size of the adjustments down at LMN and MCN.*

Location	CurrentSpill	New Spill	Rationale
TDDO	128	128	Did not spill to cap.
CWMW	100	100	No change. TDG is low but is also lagging current operation change. TDG should come up late this afternoon and remain consistent around 115%.
MCPW	175	170	MCN tailwater TDG 12/24 high avg = 120.5%
LMNW	45	40	IHR forebay TDG 12/24 high avg = 116.1%

Date *17-Jun-00*

Comments

Location	CurrentSpill	New Spill	Rationale
LGNW	60	60	No change. 12 high/24 avg - 119.97%. Hold current spill for next 24 hour period and review again.
LGSW	52	50	12 high/24 avg = 120.1% Reduce slightly.
LMNW	40	37	LMNW 12/24 avg = 119% IHR forebay = 116.1%
CWMW	110	110	No change. TDG still rising at WRNO and SKAW. Review tomorrow to see where the values top out at.

Date *18-Jun-00*

Comments

Location	CurrentSpill	New Spill	Rationale
LGSW	50	45	LMN forebay over 115%
CWMW	110	105	Camas TDG over 115%
LMNW	37	32	IHR forebay over 115%

Date *20-Jun-00*

Comments

Location	CurrentSpill	New Spill	Rationale
IDSW	105	105	No change. Not spilling to cap.
LGNW	60	0	Cease spill in order to start barging fish.
JHAW	160	160	No Change. Not spilling to cap.

LMNW	27	0	Cease spill in order to start barging fish.
LGSW	42	0	Cease spill in order to start barging fish.
MCPW	170	170	No change. Not spilling to cap.
TDDO	128	128	No change. Not spilling to cap.

Date *21-Jun-00*

Comments

Location	*CurrentSpill*	*New Spill*	*Rationale*
CWMW	105	100	Camas TDG levels over 115%

Date *23-Jun-00*

Comments *With the stopping of spill this week in the Snake, the TDG levels in the Snake have been dropping. The lower Columbia is not spilling to the caps so the gas levels in the lower Columbia also dropping.*

Location	*CurrentSpill*	*New Spill*	*Rationale*
CWMW	100	110	Max was 115.0%. High 12-hour for yesterday was 115.87%.
SKAW	100	110	Max was 114.7%. Some hourly values in the last 12 hours are well below even 115%.
WRNO	100	110	Max was 114.7%. Some of the hourly values in the last 12 hours are well below even 115%

Date *28-Jun-00*

Comments

Location	*CurrentSpill*	*New Spill*	*Rationale*
TDDO	128	100	Reduce spill to 100. Appears to be a drastic reduction however, the project has not been spilling to cap. To effect a reduction in the gas level at BON the cap must be lowered to within the current operating range of the dam.
CWMW	120	115	Project exceeded the spill cap last night. Can not directly evaluate spill cap at 120. Reduce spill to 115 based on increased forebay TDG level. CWMW 12/24 TDG = 119.1%

Date *29-Jun-00*

Comments

Location	*CurrentSpill*	*New Spill*	*Rationale*
TDDO	100	97	BON forebay 12/24 high avg = 115.3%

CWMW	115	110	CWMW 12/24 high avg >120% TDG.

Date *03-Jul-00*

Comments

Location	***CurrentSpill***	***New Spill***	***Rationale***
CWMW	115	115	When BON starts to spill tonight they will spill to the gas cap for the next three days (per schedule). Based on stable temps, the adjustment to 115 yesterday appears to be sufficient to carry into 24 hour spill to gas cap.

Date *06-Jul-00*

Comments

Location	***CurrentSpill***	***New Spill***	***Rationale***
CWMW	110	100	Reduction yesterday from 115 to 110 kcfs appeared to slightly increase the TDG levels at WRNO and SKAW. Current SKAW 12/24 avg = 121% CWMW = 118% Reduce by 10 today to bring levels back under caps.
JHAW	160	140	The project TDG level is aroun 117% The spill cap, at 160, would put the project over the gas cap. This is a "just in case" movement down of the gas cap.

Date *14-Jul-00*

Comments

Location	***CurrentSpill***	***New Spill***	***Rationale***
LGSW	42	30	LGS is in a period of no spill. On Monday (17 July) all power generation units will be out for maintenance. To maintain river flow for fish, hopefully, under the 120/115% gas cap spill is being set at 30 kcfs based on the 60% DGAS study.
CWMW	110	113	

Date *17-Jul-00*

Comments

Location	***CurrentSpill***	***New Spill***	***Rationale***
CWMW	113	108	4 hourly readings at WRNO were 123 + %. Reduce by 5 KCFS to stay below absolute ceiling of 125%.
DWQI	0	0	Decreasing spill between 1400 and 1900 which is the time period where the TDG level appears to peak. Change instructions to maintain water temp between 48.0-48.5. Watch how this affects the TDG level during the 24 hours especially 1900-1400.

Appendix I
Section 1: USGS - Portland District Fixed Monitoring Stations
Section 2: Walla Walla District TDG Report

U.S. Department of the Interior
U.S. Geological Survey

Data-Collection Methods, Quality-Assurance Data, and Site Considerations for Total Dissolved Gas Monitoring, Lower Columbia River, Oregon and Washington, 2000

Water-Resources Investigations Report 01–4005

Prepared in cooperation with the
U.S. ARMY CORPS OF ENGINEERS

USGS
science for a changing world

Cover Photograph. Columbia River at John Day Dam, April 2000. (*Photograph by Amy Brooks, U.S. Geological Survey)*

U.S. Department of the Interior
U.S. Geological Survey

Data-Collection Methods, Quality-Assurance Data, and Site Considerations for Total Dissolved Gas Monitoring, Lower Columbia River, Oregon and Washington, 2000

By DWIGHT Q. TANNER AND MATTHEW W. JOHNSTON

Water-Resources Investigations Report 01–4005

Prepared in cooperation with the
U.S. ARMY CORPS OF ENGINEERS

Portland, Oregon: 2001

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

For additional information contact:

District Chief
U.S. Geological Survey
10615 S.E. Cherry Blossom Drive
Portland, OR 97216-3159
E-mail: info-or@usgs.gov
Internet: http://oregon.usgs.gov

Copies of this report can be purchased from:

USGS Information Services
Box 25286, Federal Center
Denver, CO 80225-0046
Telephone: 1-888-ASK-USGS

Suggested citation:

Tanner, D.Q., and Johnston, M.W., 2001, Data-collection methods, quality-assurance data, and site considerations for total dissolved gas monitoring, lower Columbia River, Oregon and Washington, 2000: U.S. Geological Survey Water-Resources Investigations Report 01–4005, 19 p.

CONTENTS

FIGURES

TABLES

Data-Collection Methods, Quality-Assurance Data, and Site Considerations for Total Dissolved Gas Monitoring, Lower Columbia River, Oregon and Washington, 2000

By Dwight Q. Tanner and Matthew W. Johnston

ABSTRACT

Excessive total dissolved gas pressure can cause gas-bubble trauma in fish downstream from dams on the Columbia River. In cooperation with the U.S. Army Corps of Engineers, the U.S. Geological Survey collected data on total dissolved gas pressure, barometric pressure, water temperature, and probe depth at eight stations on the lower Columbia River from the John Day forebay (river mile 215.6) to Camas (river mile 121.7) in water year 2000 (October 1, 1999, to September 30, 2000). These data are in the databases of the U.S. Geological Survey and the U.S. Army Corps of Engineers. Methods of data collection, review, and processing, and quality-assurance data are presented in this report.

INTRODUCTION

The U.S. Army Corps of Engineers (USACE) operates several dams in the Columbia River Basin, which encompasses 259,000 square miles of the Pacific Northwest. These dams are multipurpose facilities that fill regional needs for flood control, navigation, irrigation, recreation, hydropower production, fish and wildlife habitat, water-quality maintenance, and municipal and industrial water supply. When water is released over the spillways of these dams, air is entrained in the water, sometimes increasing the concentration of total dissolved gas (TDG) downstream from the spillways in excess of the U.S. Environmental Protection Agency's water-quality criterion of 110-percent saturation for the protection of freshwater aquatic life. Concentrations above this criterion have been shown to cause gas-bubble trauma in fish and adversely affect other aquatic organisms (U.S. Environmental Protection Agency, 1986). USACE minimizes spill and regulated streamflow in the region to minimize the production of excess TDG downstream from its dams. USACE collects real-time TDG data (data available within about 4 hours of current time) upstream and downstream from the dams in a network of fixed-station monitors.

Background

Real-time TDG data are vital to USACE for dam operation and for monitoring compliance with environmental regulations. The data are used by water managers to maintain water-quality conditions that facilitate fish passage and survival in the lower Columbia River. The U.S. Geological Survey (USGS), in cooperation with the Portland District of USACE, has collected TDG and related data in the lower Columbia River every year beginning in 1996. A report was published in 1996 that contained a description of the methods of data collection, the quality-assurance program, and summaries of data (Tanner and others, 1996).

Data-collection methods and quality-assurance plans have changed significantly since 1996. In water year 2000, new TDG/temperature probes and new methods of calibration in the laboratory and in the field were used.

To provide a suitable data set for water managers to model TDG in the lower Columbia River, the real-time hourly data for water year 2000 were corrected or deleted to reflect measurements made during instrument calibration. The reviewed and corrected hourly data are stored in a USGS data base (Automated Data Processing System—ADAPS) and in a USACE data base at http://www.nwd-wc.usace.army.mil/TMT/tdg_data.

Purpose and Scope

The purpose of TDG monitoring is to provide USACE with (1) real-time data for managing streamflows and TDG levels upstream and downstream from its project dams in the lower Columbia River and (2) reviewed and corrected TDG data to evaluate conditions in relation to water-quality criteria and to develop a TDG data base for modeling the effect of various management scenarios of streamflow and spill on TDG levels.

This report describes the data-collection techniques and quality-assurance data for the TDG monitoring program on the Columbia River from the forebay of the John Day dam (river mile [RM] 215.6) to Camas (RM 121.7). Data for water year 2000 included total dissolved gas pressure, barometric pressure, and water-temperature at eight fixed stations on the lower Columbia River (fig. 1, table 1).

Acknowledgments

We wish to acknowledge the aid and funding support of the U.S. Army Corps of Engineers. Our special thanks to James L. Britton (USACE) for technical and logistical support of the project. The authors also acknowledge Amy Brooks and Tirian Mink (USGS) for assistance in data collection and for preparing summaries of data. Howard E. Harrison, formerly of the USGS, helped develop several of the data-collection and quality-assurance protocols.

METHODS OF DATA COLLECTION

Instrumentation

Instrumentation at each fixed station consisted of a TDG probe, an electronic barometer, a data-collection platform (DCP), and a power supply. The TDG probe was manufactured by Hydrolab Corporation. The probe had individual sensors for TDG, temperature, and probe depth (unvented sensor). The TDG sensor consisted of a cylindrical framework wound with a length of Silastic

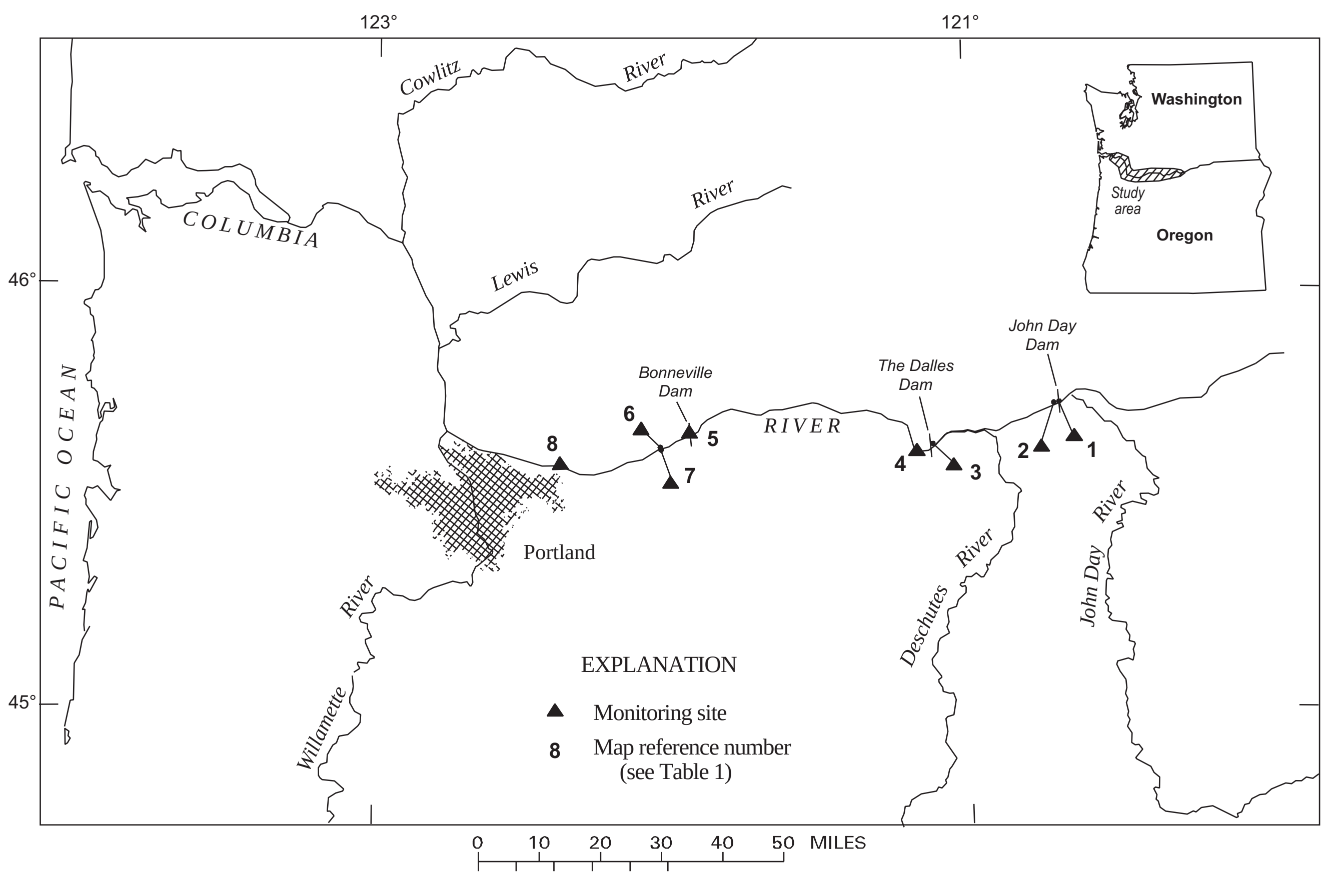


Figure 1. Total dissolved gas fixed stations, lower Columbia River, Oregon and Washington, water year 2000.

Table 1. Total dissolved gas fixed stations, lower Columbia River, Oregon and Washington, water year 2000

[Map reference number refers to figure 1; USACE, U.S. Army Corps of Engineers; Columbia River mile locations were determined from U.S. Geological Survey (USGS) 7.5-minute topographic maps; stations are referenced by their abbreviated name in this report]

Map reference number	USACE site identifier	Columbia River mile	USGS station number	USGS station name (abbreviated station name)	Latitude	Longitude	Period of record
1	JDA	215.6	454257120413000	Columbia River at John Day Dam forebay, Washington (John Day forebay)	45˚ 42’ 57”	120˚ 41’ 30”	March 24 – September 19
2	JHAW	214.7	454249120423500	Columbia River, right bank, near Cliffs, Washington (John Day tailwater)	45˚ 42’ 49”	120˚ 42’ 35”	March 23 – September 19
3	TDA	192.6	453712121071200	Columbia River at The Dalles Dam forebay, Washington (The Dalles forebay)	45˚ 37’ 12”	121˚ 07’ 12”	March 24 – September 20
4	TDDO	188.9	14105700	Columbia River at The Dalles, Oregon (The Dalles downstream)	45˚ 36’ 27”	121˚ 10’ 20”	March 23 – September 19
5	BON	146.1	453845121562000	Columbia River at Bonneville Dam forebay, Washington (Bonneville forebay)	45˚ 38’ 45”	121˚ 56’ 20”	Year-round
6	SKAW	140.5	453651122022200	Columbia River, right bank, near Skamania, Washington (Skamania)	45˚ 36’ 51”	122˚ 02’ 22”	February 23 – September 18
7	WRNO	140.4	453630122021400	Columbia River, left bank, near Dodson, Oregon (Warrendale)	45˚ 36’ 30”	122˚ 02’ 14”	Year-round
8	CWMW	121.7	453439122223900	Columbia River, right bank, at Washougal, Washington (Camas)	45˚ 34’ 39”	122˚ 22’ 39”	February 24 – September 18

(dimethyl silicon) tubing. The tubing was tied off at one end and the other end was connected to a pressure transducer. After the TDG pressure in the river equilibrated with the gas pressure inside the tubing (about 15 to 20 minutes), the pressure transducer produced a measure of the TDG pressure in the river. The water-temperature sensor was a thermocouple. The barometer was contained in the display unit of the Model TBO-L, a total dissolved gas meter manufactured by Common Sensing, Inc.

The TDG probe was connected by a heavy-duty, weatherproof cable to a Sutron Model 8200 DCP. The DCP had three basic functions: sensor interfacing, data storage, and data transmission to the Geostationary Operational Environmental Satellite (GOES) system (Jones and others, 1991). A crossed Yagi antenna was connected to the DCP using a coaxial cable. The antenna was mounted on a mast to provide transmission to the GOES system.

The barometer, TDG probe, and the DCP were powered by a 12-volt gelled-electrolyte battery. The battery was charged by a regulated-voltage circuit from a solar panel and/or a 120-volt alternating-current line.

The DCP was programmed to record and transmit five parameters: barometric pressure (in millimeters of mercury), TDG pressure (in millimeters of mercury), probe depth (in feet), water temperature (in degrees Celsius), and battery voltage (in volts). Battery-voltage data were monitored to determine whether the instrumentation was receiving adequate power. The data for each parameter were logged electronically every hour, on the hour, and stored in the DCP memory. Every 4 hours, the DCP transmitted the most recent 12 hours of logged data to the GOES satellite. Consequently, each piece of data was transmitted three times to protect against data loss. The GOES satellite retransmitted the data to a direct readout ground station, where the data were automatically decoded and transferred to the USACE data base (Columbia River Operation Hydromet Management System—CHROMS), and to the USGS ADAPS data base. During the fixed-station calibration visits, the DCP-stored data were downloaded to a palmtop computer. When it was necessary to fill in any real-time data lost during satellite transmission, these data were supplied to USACE and also loaded into the database at the USGS office in Portland, Oregon.

At one site, John Day tailwater, two TDG probes were installed inside the same probe housing, which was perforated at the end and extended into the flow of the Columbia River. The primary probe was at the distal end of the plastic pipe and the secondary probe was located about 1 foot (measured vertically) above the first. This was done for the following reasons: (1) to ensure that data were reliably collected at this important site and (2) to provide an assessment of the variability of the TDG measurement.

Calibration of Instruments in the Laboratory

The fixed station monitors were calibrated every 2 weeks from March 10 to September 15, 2000, and every 3 weeks for the remainder of the year, at which time Warrendale and Bonneville forebay were the only sites in operation. The general procedure was to check the operation of the TDG probe in the field without disturbing it, replace the field probe with one that had just been calibrated in the laboratory, and then check the operation of the newly deployed field probe. The details of the laboratory calibration procedure follow.

Each time a TDG probe was removed from its 2- or 3-week deployment in the river, it was calibrated in the Oregon District laboratory before being redeployed. First, the TDG value in millimeters of mercury was measured in ambient conditions with the TDG membrane still attached to the sensor and compared to the ambient barometric pressure as measured by a handheld aneroid barometer (fig. 2, item 1). (The aneroid barometer was calibrated every 2 weeks at the National Weather Service facility in Portland, Oregon.) If the measurement by the TDG probe and the measurement by the aneroid barometer were approximately equal, this check was considered acceptable.

Pressure calibrations were done using a Netech DigiMano 2000 digital pressure gage, which was certified according to standards of the National Institute of Standards and Technology (NIST). The end of the TDG probe containing the sensors was put in a plastic pressure chamber and the pressure was increased 200 mm Hg (millimeters of mercury) above the ambient barometric pressure (fig. 2, item 2). The pressure measured by the TDG sensor should increase gradually, until it reaches a level approximately 200 mm Hg above barometric pressure, within about 10 minutes. This would indicate that the pressurized air was penetrating the membrane at a gradual rate. On occasions when there was an opening torn in the membrane, the pressure measured by the TDG sensor would increase rapidly, indicating that the membrane should be replaced.

HYDROLAB LABORATORY PROCEDURES

To be done when a Hydrolab is brought in from a 2 or 3-week deployment.

Hyrolab # 37603 Lab barometer ID dqt
TDG sensor # 63369 Date baro last calib. 5/18/00
Site Hyd. was deployed SKAW Today's date 6/13/00
Date removed 6/5/00 Checked by TM

1. TEST LOW CALIBRATION WITH MEMBRANE ATTACHED.

Lab BP 765 mm Hydrolab Pt 762 mm Time 1403

2. TEST HYDROLAB WITH DIGITAL PRESSURE GAGE AND PRESSURE CHAMBER.
Lab BP + 200mm = 965 mm

Before applying 200 mm pressure Hydrolab Pt 762 mm Time 1403
After applying pressure Hydrolab Pt 964 mm Time 1412

3. TEST HYDROLAB WITH CLUB SODA.

Before soda test Hydrolab Pt 760 mm Time 1519
High pressure, soda test Hydrolab Pt 1011 mm Time 1520
Low pressure, after soda test Hydrolab Pt 728 mm Time 1522

(If the Hyd. does not perform well on #1 - #3 above, re-evaluate the corresponding site record.)

Remove TDG membrane, clean the membrane, air dry, store in dessicator.
Allow TDG sensor to air dry for at least 24 hours.
Then test Hydrolab before redeployment, below.

---

1. CALIBRATE TDG WITH DIGITAL PRESSURE GAGUE.
Date 6/14/00
Time 1415

Lab BP 762 mm
Hydrolab Pt 760 mm

862 860
Baro+100mm expected/meas.

962 961
Baro+200mm expected/meas.

1062 1061
Baro+300mm expected/meas.

If any readings are >2 mm off, do a 2-point calibration at barometric pressure and barometric pressure + 200 mm and note below.

2. INSTALL DRY MEMBRANE AND INSTALL THE SENSOR GUARD.

3. TEST HYDROLAB WITH CLUB SODA. 6/15/00 baro=767

Before soda test Hydrolab Pt 771 mm Time 0907
High pressure, soda test Hydrolab Pt 1002 mm Time 0908
Low pressure, after soda test Hydrolab Pt 746 mm Time 0909

4. CLEAN AND DRY THE HYDROLAB.

5. CHECK MEMBRANE FOR INTERNAL MOISTURE AFTER THE OUTSIDE OF THE MEMB. HAS HAD TIME TO DRY

Label as ready for field deployment, with date. Completed Date 6/16/00 Time 1400

Figure 2. Laboratory calibration form.

Subsequently, the TDG membrane / TDG sensor units were tested for responsiveness to supersaturation by inserting the probe into a container filled with supersaturated carbonated water (club soda). If the membrane/sensor was operating correctly, the measured TDG rose to at least 1,000 mm Hg in 2 to 3 minutes (fig. 2, item 3). If the response was not this large, the membrane was replaced.

Next, the TDG membrane was cleaned with a squirt bottle of tap water, then removed from the sensor. The TDG membrane was dried in a desiccator for at least 24 hours, and, at the same time, the TDG sensor was air dried at room temperature. This step was important because water sometimes collected inside the tubular membrane due to condensation. If the condensation is not removed, it can slow the equilibration of air pressure between the outside of the membrane and the TDG sensor.

After the TDG membrane and sensor had been dried, the TDG sensor, with the membrane still unattached, was tested at ambient pressure conditions (i.e. barometric pressure, as measured by the aneroid barometer) and at added pressures of 100 mm Hg, 200 mm Hg, and 300 mm Hg measured by the pressure gage, which was the primary standard (lower half of fig. 2, item 1). For example, using the barometric pressure of 760 mm Hg, the added pressures of 0, 100, 200, and 300 mm Hg correspond to TDG percent saturations of 100%, 113.2%, 126.3%, and 139.5%, respectively. The results of these calibrations for water year 2000 are shown in figure 3. Almost all of the calibrations were within 1-percent saturation of total dissolved gas. One outlier, for 0 mm Hg added pressure at Skamania, was 5.3 percent larger than expected. This result indicated that the sensor was defective, and it was replaced.

If any of the measurements differed more than 3 mm Hg from the primary standard, the sensor was calibrated at two points, barometric pressure and barometric pressure plus 200 mm Hg. Then the calibration of the TDG sensor was checked a second time according to the procedure above to be sure that it was correctly calibrated at the various pressures.

After the pressure check and calibration (if needed) of the TDG sensor, the dried membrane was reattached to the sensor, and the sensor guard was screwed back on the probe. Then another test was done for responsiveness to supersaturation with “club soda” (carbonated water) (lower half of fig. 2, item 3). Again, if the membrane/sensor was operating correctly, the measured TDG rose to at least 1,000 mm Hg in 2 or 3 minutes. If the response was not this large, the membrane was replaced. This second test, with club soda, was done because the process of installing the sensor guard had been found to abrade the TDG membrane, so the test ensured that the membrane was still functional.

The final step was to inspect the inside of the membrane for moisture (lower half of fig. 2, item 5.) If no moisture was visible, the TDG probe was labelled as ready for field deployment.

In addition to the TDG probes that were calibrated for replacement in the field each 2 to 3 week calibration interval, one TDG probe was calibrated every 2 to 3 weeks for use in the field as a secondary standard. This was the probe designated “Lab” on figure 3. The TDG sensor was calibrated in the manner described above, and, additionally, the temperature calibration was checked in a water bath at a temperature near to the ambient river temperature at the time. The temperature displayed for the probe thermistor was compared to the temperature as read to the nearest 0.1 degrees Celsius with a NIST-traceable mercury thermometer. The TDG temperature probe for the “Lab” Hydrolab could not be adjusted to display the correct temperature, so the needed adjustment (if any) was recorded for later use during the field calibrations.

Calibration of Instruments in the Field

The fixed station monitors were calibrated every 2 weeks from March 10 to September 15, 2000, and every 3 weeks for the remainder of the year, at which time Warrendale and Bonneville forebay were the only sites in operation. The general procedure was to check the operation of the field probe without disturbing it, then replace the field probe with one that had been recently calibrated in the laboratory (as described above) and check the operation of the newly deployed field probe. The details of the field procedure follow.

The first step was to fill out the heading of the field sheet (fig. 4) indicating site, date and time, weather conditions, and identification of the equipment at the site. Then the “LAB” TDG probe (the secondary standard) was placed in the river at a location adjacent to the field probe (fig. 4, item 1). The instrument shelter (a waterproof metal enclosure) was checked to ensure that the vent was unobstructed so that the barometer could effectively measure the ambient barometric pressure (fig. 4, item 2).

A palmtop computer was connected to the DCP, allowing for data retrieval and program adjustment and

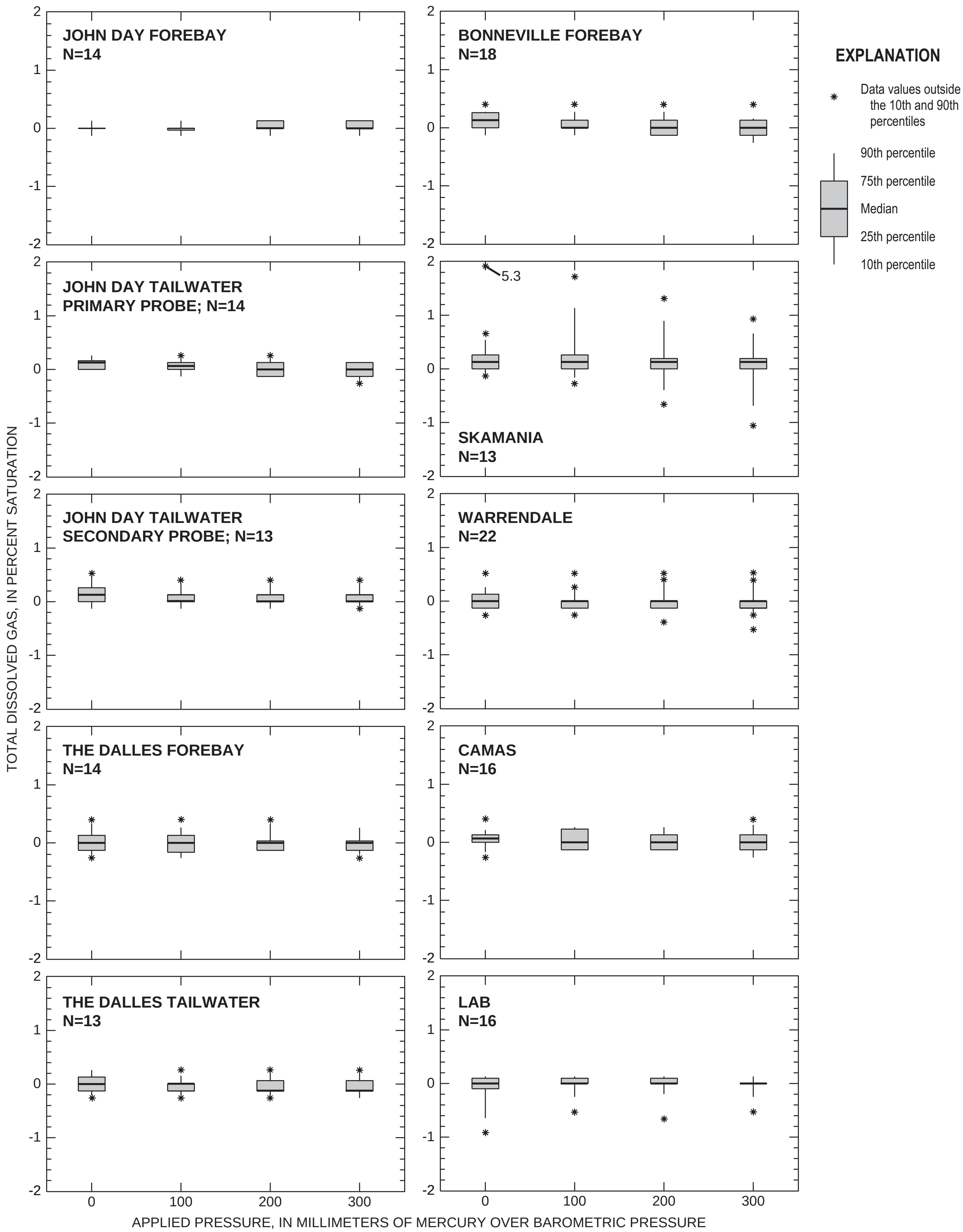


Figure 3. Accuracy of total dissolved gas sensors when compared to a primary standard after field deployment. (Total dissolved gas value from primary standard minus value from field total dissolved gas probe.)

HYDROLAB TDG FIELD INSPECTION/CALIBRATION SHEET (1/00 version)
----- USGS Portland, Oregon (503)251-3200 ---------------------

Site ID: BON Date: 5-24-00 Arrive time: 1020
Personnel: Brooks Purpose: calibration
Weather: sunny Air temperature: 20.8 C
Observed spill conditions: All gates
DCP# 37409 TBO# 19
Lab Hydrolab # 33674 Date last cal. 5-18-00
Lab Barometer ID DQT Date last cal. 5-18-00

1. **WITHOUT MOVING THE OLD FIELD HYDROLAB, PLACE LAB HYDROLAB IN RIVER AT DEPTH OF OLD FIELD HYDROLAB** Time: 1025

2. IS SHELTER VENT OBSTRUCTED (Y/N): N

3. **CONNECT COMPUTER AND CHECK DCP**
Dump logged data to file: 5/12/2000 .LOG (3 kb)
Most recent logged data: time 1700 baro 763 temp 14.64 depth 17.46 Pt 836
DCP clock time: 17:33:30 GMT time (watch): 17:33:29
Reset clock (Y/N): N
Recording status (check one): X ON&TX, ___ ON&FT, ___ ON, ___ OFF
Antenna angle approx. 35-40 degrees to horizon (Y/N): Y
Antenna direction approx. 180 degrees - south (Y/N): Y
Battery minimum: 13.26 VDC Battery maximum: 13.34 VDC
Next transmission 18:11:10 GMT Error messages (Y/N): N (log in notes)
Clear status (Y/N): Y

4. **CHECK POWER AND CHARGING SYSTEM WITH MULTI-METER**
AC (at outlet): 120.0 VAC
DISCONNECT battery IF next transmission NOT imminent
BATTERY (at poles): 13.33 VDC
REGULATOR (at leads to battery from DCP = 13.8VDC/.75A): 13.29 VDC
RECONNECT battery, then disconnect right side DCP bus bar
SOLAR PANEL OR AC/DC CONVERTOR (at PWR IN screws): 13.76 VDC
RECONNECT bus bar

5. BAROMETRIC PRESSURE

763 mm - 760 mm = 3 mm IF |*5*| > 10mm, replace TBO
Lab BP TBO BP *5*

763 mm - 764 mm = -1 mm
Lab BP DCP BP Back Shift

Reset DCP Old offset 0.001 New offset 0 Time: 1037

6. TEMPERATURE Uncorrected Lab WT = 14.61 C

14.71 C - 14.67 C = +.04 C Time: 1038
Corrected Lab WT Old Field Hyd WT Back Shift

NOTES: ______________________________

Page 1

Figure 4. Field inspection/calibration sheet.

7. AFTER A MIN. OF 15 MIN. IF LAB & OLD FIELD HYD PT READINGS HAVE NOT CHANGED 1 MM./2 MIN. AFTER SHAKING **LAB** HYDROLAB OR IF LAB & OLD FIELD HYD ARE CHANGING BUT DIFFERENCE IS CONSTANT:

855 mm - 853 mm = 2 mm Time: 1054

Lab Hyd PT Old Field Hyd PT Back Shift

855-763=92/23

current is shifting lab probe up & down a few feet

Time	Lab Pt	Old Fld Pt
1039	868	836
1045	860	851
1047	857	852
1049	856	853
1050	853	853

8. **CALCULATE MINIMUM SENSOR COMPENSATION DEPTH (MSCD)**
   (Lab PT - Lab BP) / 23 = 4.00 ft.
   Sensor depth at arrival: 17.46 ft.

9. IF OLD FIELD HYD NOT AT OR BELOW MSCD, LOWER OLD FIELD AND LAB HYD TO MSCD. ALLOW TO STABILIZE AND RECORD OLD LAB AND FIELD PT AND WT IN NOTES.

10. **REMOVE OLD FIELD HYDROLAB FROM RIVER** Record Old Fld. Hydrolab # 33768 Time: 1055

11. **CHECK DEPTH PARAMETER ON OLD FIELD HYDROLAB**
    Depth reading (Hydrolab out of the river) -0.07 ft Time: 1056

12. **CONNECT NEW FIELD HYDROLAB, CALIBRATE DEPTH PARAMETER, CHECK Pt IN AIR**
    New Field Hydrolab # 37599 Last caibrated 5-18-00
    Depth reading before zeroing -0.13 ft Reset depth to 0.0 ft
    Record Pt reading in ambient air 761 mm Time: 1057

13. **DEPLOY NEW FIELD HYDROLAB IN RIVER AT 15' OR MAXIMUM DEPTH OF SENSOR HOUSING**
    Sensor depth: 16.32 ft Time: 1103

14. TEMPERATURE Uncorrected Lab WT = 14.62 C

    14.72 C - 14.66 C = +.06 C
    Corrected Lab WT New Field Hyd WT

    Reset DCP Old offset 0 New offset +.1 Time: 1106

15. AFTER A MIN. OF 15 MIN. IF LAB & NEW FIELD HYD PT READINGS HAVE NOT CHANGED 1 MM./2 MIN. AFTER SHAKING **NEW FIELD** HYDROLAB OR IF LAB & NEW FIELD HYD ARE CHANGING BUT DIFFERENCE IS CONSTANT:

    852 mm - 855 mm = -3 mm Time: 1124
    Lab Hyd PT New Field Hyd PT *15*

Time	Lab Pt	New Fld Pt
1104	853	855
1122	852	856

    IF |*15*| is > 10 mm, replace new Hydrolab with a backup, or do A and B

A. TEST NEW FIELD AND LAB HYD. WITH CLUB SODA:
   New Fld. Hyd. ___________ mm Time: ________
   Lab Hyd. ___________ mm Time: ________

B. TEST NEW FIELD AND LAB HYD. WITH PRESSURE GAGE AND CHAMBER:
   New Fld. Hyd. ambient___________ mm; plus 200mm__________ mm Time: ________
   Lab Hyd. ambient___________ mm; plus 200mm__________ mm Time: ________

IF NEW FLD. HYDROLAB FAILS EITHER TEST, REPLACE IT WITH A BACKUP HYDROLAB.
IF LAB HYDROLAB FAILS EITHER TEST, USE A BACKUP HYDROLAB TEMPORARILY AS THE LAB METER.

16. **CHECK DCP OFFSET FOR Pt = ZERO** Y/N: Y

17. **SAVE SETUP, CHECK RECORDING STATUS = "ON&TX", DISCONNECT LAPTOP** Y/N: Y

Equipment changed other than Hydrolab (Y/N, item): N, _____________ End time: 1126

NOTES: ____

Page 2

Figure 4. Field inspection/calibration sheet—Continued.

checking (fig. 4, item 3). The data that were logged by the DCP since the last visit were downloaded to the palmtop computer so they could be available in the event that any data were not transmitted by the satellite system. The clock in the DCP was checked and adjusted, if necessary. Antenna alignment and recorded battery voltages were checked and recorded.

The power and charging systems were checked using a digital multimeter (fig. 4, item 4). Some of the sites had 120-volt alternating-current (AC) power service; the voltage of those supplies was checked. With the battery disconnected, its voltage was measured, and the circuit that charges the battery (the regulator) was checked. Finally, the battery was reconnected, and the voltage output of the solar panel or AC/DC converter was checked before its input to the voltage regulator.

The field-deployed electronic barometer was checked and adjusted, if necessary (fig. 4, item 5). The measurement from the secondary standard aneroid barometer ("Lab BP" on figure 4) was compared to the measurement made by the field electronic barometer and displayed by the DCP ("DCP BP" on fig. 4). If there was a difference, the back shift was applied to change the offset value in the DCP program. After this step, the DCP would display the same barometric pressure (to the nearest millimeter of mercury) as the secondary standard, the aneroid barometer. The results of the field calibrations of the electronic barometers at the fixed stations are shown in figure 5. Most of the time, the field barometer was within 1 mm Hg of the secondary standard. At The Dalles forebay site, the spread of data was widest—between plus and minus 2 mm Hg. This probably was the result of a variable signal from the electronic barometer, which resulted in the offset being adjusted one way on one calibration visit and the other way on the next calibration visit.

The performance of the field temperature sensor was documented (fig. 4, item 6). The water temperature measurement made by the secondary standard TDG probe ("Corrected Lab WT") was compared to the measurement made by the nearby field-deployed TDG probe ("Old Field Hyd WT"). The differences were usually less than 0.1ºC (degrees Celsius), indicating the accuracy when compared to the secondary standard (fig. 6).

Performance of the fixed-station TDG sensor was documented (fig. 4, item 7). Values of TDG obtained by the secondary standard TDG sensor ("Lab Hyd PT") were compared to the values obtained by the fixed-station TDG sensor ("Old Field Hyd PT"). For this

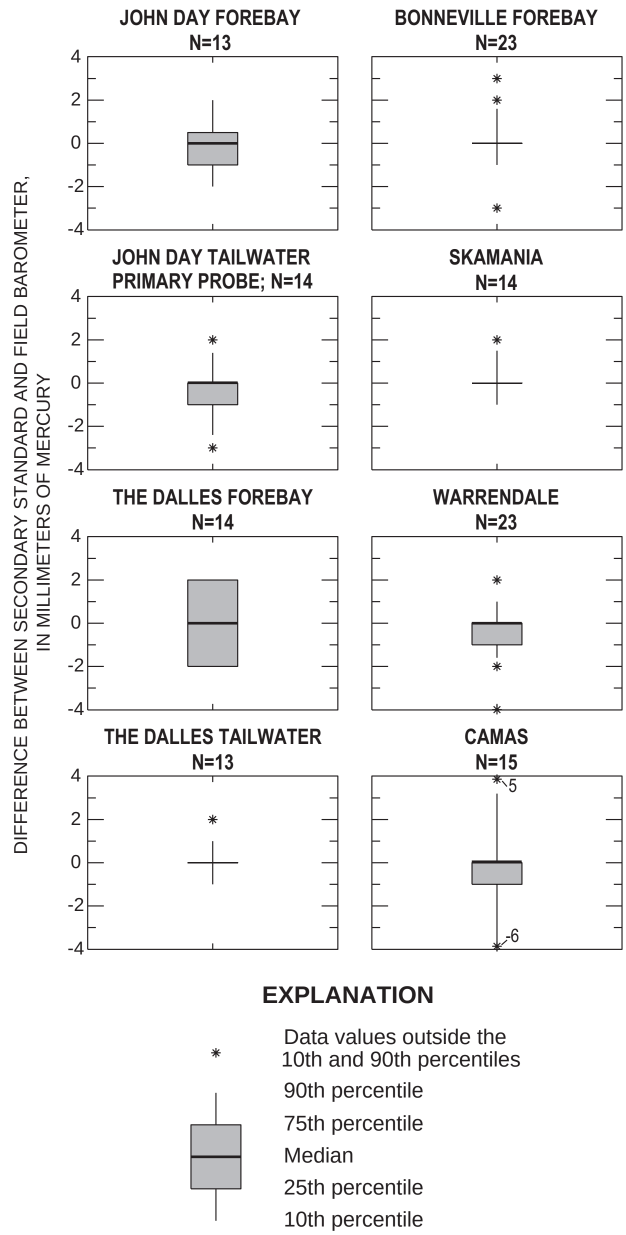


Figure 5. Difference between the secondary standard and the field barometers.

comparison, it was necessary to wait until the secondary standard reached equilibrium in the river. Usually this equilibration process took about 30 minutes and was considered to be complete when the reading for each probe did not change even 1 mm Hg for a period of 2 minutes. At most sites, there was usually less than a 1 percent TDG difference between the secondary standard and the fixed-station monitor (fig. 7.) At The Dalles site once, and at the Camas site three times, the TDG measurement from the fixed-station monitor was more than 10 percent larger than the measurement from the secondary standard (fig. 7). These were times when

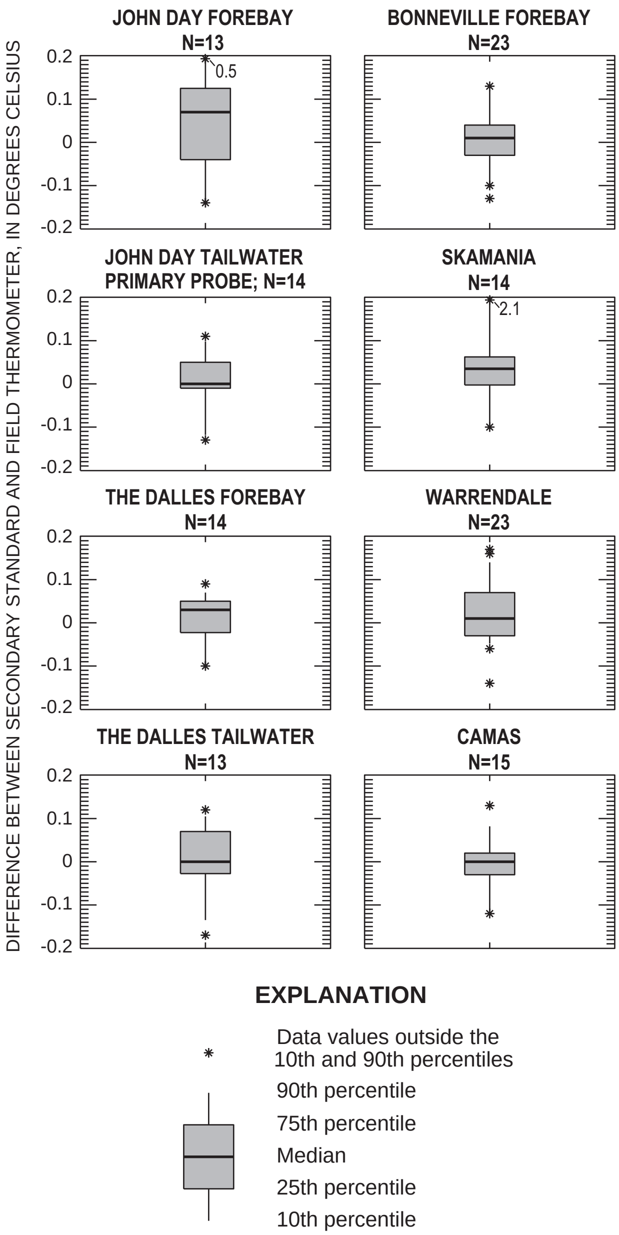


Figure 6. Difference between the secondary standard and the field thermometers.

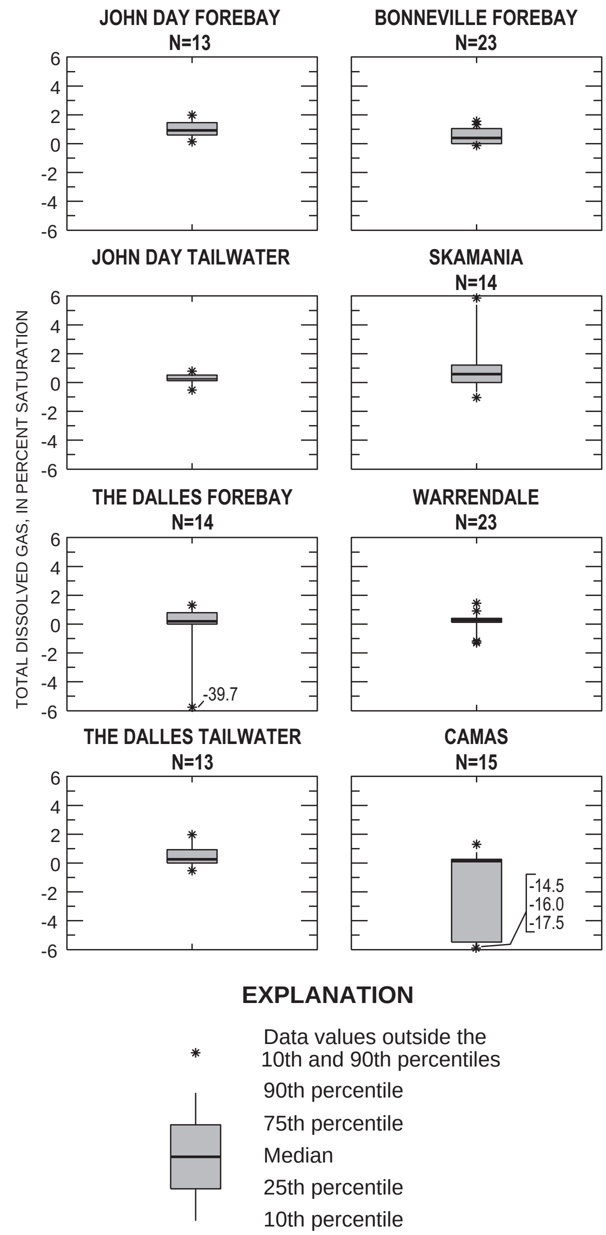


Figure 7. Total dissolved gas difference between the field probe and lab probe initially.

the TDG membrane had been broken, resulting in incorrect TDG measurements.

The minimum compensation depth was calculated and recorded (fig. 4, item 8). This depth, calculated according to a formula derived from Colt (1984, page 104), is the depth above which degassing will occur, due to the decreased hydrostatic pressure. In order to measure TDG accurately, the probe must be deeper than the calculated compensation depth. If the probe was not below minimum compensation depth and it was physically possible to have it that deep, the TDG was measured at the larger depth (fig. 4, item 9).

The probe from the fixed station was removed from the river and the depth parameter was checked when it was above the water surface (fig. 4, items 10 and 11). The depth reading usually differed from zero by about 0.1 or 0.2 feet. These differences were due to the fact that the depth sensor on the TDG probe was not vented to the outside atmosphere, so that changes in barometric pressure affected the measured depth of the TDG probe.

The newly calibrated TDG probe was connected to the fixed-station equipment, the functions of depth and TDG measurement were checked, and the zero point for depth measurement was calibrated (fig. 4, item 12).

The TDG probe was allowed 5 to 10 minutes to equilibrate in the river then the temperature measurement function was checked and calibrated (fig. 4, item 14). Using the electronic offsets in the DCP, the measurement made by the newly calibrated TDG probe was made to read the same temperature as measured by the secondary standard for temperature (the laboratory-calibrated TDG probe).

The final field calibration step (fig. 4, item 15) was to check the TDG measurement in the river made by the newly calibrated fixed-station probe against that made by the secondary standard (the laboratory-calibrated TDG probe). These two values usually were within 2 percent TDG of each other (fig. 8).

Daily Quality-Assurance Checks

Each morning, the performance of the TDG fixed stations was evaluated and e-mail concerning the status of the network was sent to involved parties, including USACE. Figures 9–11 are examples of the materials used for the daily quality-assurance checks. Figure 9 shows a checklist summarizing intersite comparisons. Figure 10 is an example of 1 of 33 pairwise graphs of TDG, barometric pressure, and temperature data from adjacent sites made during the spring and summer spill season; 1 additional graph showed the 2 TDG measurements made at the John Day tailwater site. Data for graphs of intersite comparisons were from the USGS ADAPS database, current to approximately 0600 hours on the day of the check. Also included were data from the USACE Web site showing spill and total flow below the dams at John Day, The Dalles, and Bonneville. These data were included to help explain variations of TDG that could be related to the changing operations of the dams above the fixed-station TDG monitors. For example, figure 11 illustrates the effects of changes in spill over the John Day Dam on TDG measured at the John Day tailwater site.

These quality-assurance materials were valuable for evaluating the status of the monitoring network. If data were completely missing from one site, the satellite downlink data were checked to see if signal strength, transmission time, or battery voltage data were anomalous for previous transmissions.

On occasion during these daily checks, the TDG values were observed to suddenly increase and stay constant at a larger value, without a corresponding increase

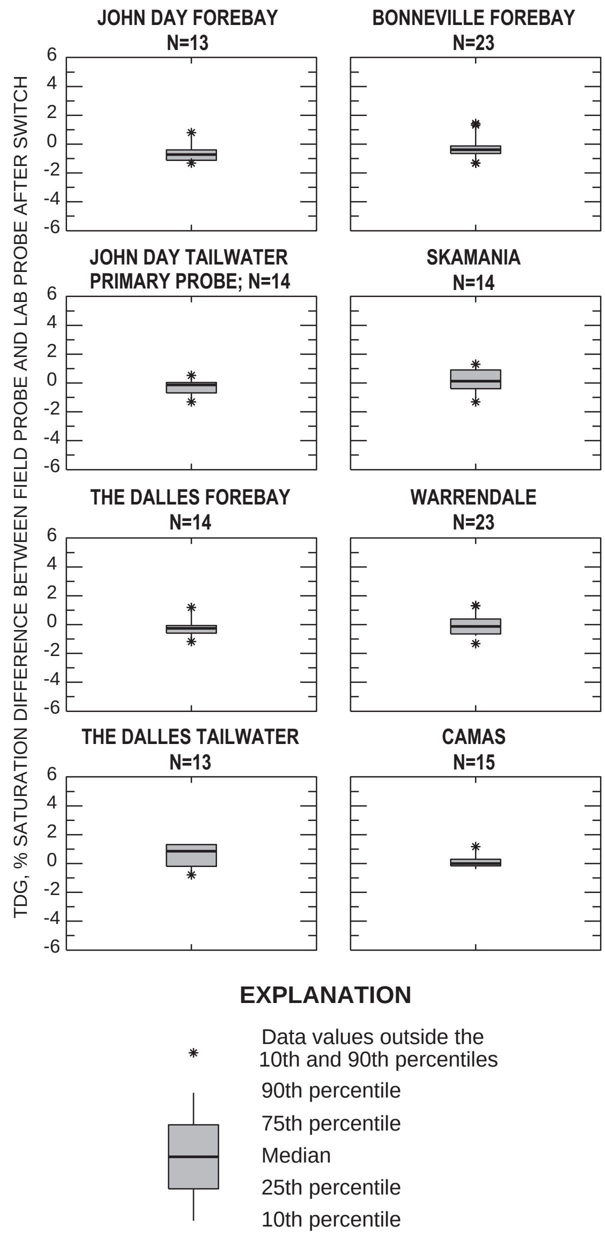


Figure 8. Total dissolved gas difference between the field probe and lab probe at the end of field calibrations.

in spill at the dam above the site. In these cases, the problems were caused by a tear or hole in the TDG membrane, which allowed water pressure to influence the TDG sensor, which should have been exposed only to the air inside the tubular TDG membrane.

When this happened, an “emergency” field trip was made to resolve the problem. In the case that there were data from a site that were known to be incorrect as a result of a damaged membrane or for any other reason, this was noted in the daily e-mail to the interested parties mentioned previously.

CHECKLIST FOR TDG DAILY CHECKS - attach to daily graphs

Date 6/23/00 Checked by Tanner

Check the 33 intersite comparison graphs back to the last day checked.
(For example, check back to Friday on Monday).

✓ Pt - No more than 25% of the hourly values are missing or anomalous
(Intersite comparisons differ < 20 mm Hg unless spill explains difference)

✓ B.P. - No more than 25% of the hourly values are missing or anomalous
(Intersite comparisons differ < 14 mm Hg)

If these conditions are not met, an emergency trip needs to be taken within the next 48 hours.

✓ Temp. - Check for intersite variations > 2.0 deg C, note to COE, but
no emergency trip is needed.

Y or N Is replot needed to clearly see data variations on any plot?
If yes - replot data and put the new plot with the daily check.

Y or N Are any data missing from ADAPS but present at COE website?
If yes - put COE data with site file.
- immediately contact our computer section to restore data to ADAPS if possible.

Y or N Were any graphs marked to explain or note any potential anomalies?
If yes - make a copy and put copy in site file.

X Send email to COE describing site status, including planned emergency trips.

If any site is other than satisfactory, include the hour of missing or questionable data, and put a copy of the email in site file.

Figure 9. Checklist for total dissolved gas daily quality-assurance checks.

Data Workup and Archive

Periodically, and at the end of the fiscal year, data for each TDG fixed-station were reviewed in-house and documented on paper files and in the USGS database. Tables and graphs of hourly value data were prepared for TDG, barometric pressure, and water temperature for each month for which data were collected. These tables and figures were screened using intersite comparisons between adjacent sites and monthly graphs of spill from appropriate dams. Any incorrect data were deleted from the database. Common causes of incorrect data included elevated TDG measurements due to torn TDG membranes (mentioned above) and missing value codes from the satellite transmissions that were interpreted by the USGS database as large measured values. An electronic file of data to be deleted was prepared for USACE.

In one case, at the Skamania site from August 30 to September 15, 2000, a linear shift was applied to the TDG data due to the gradual failure of the TDG sensor. The shifted data were incorporated into the USGS database and the same shifted data were supplied to USACE.

Ancillary data and information were also documented in paper files. Data for battery voltage after each satellite transmission were graphed on a monthly basis in order to track any problems with data transmission

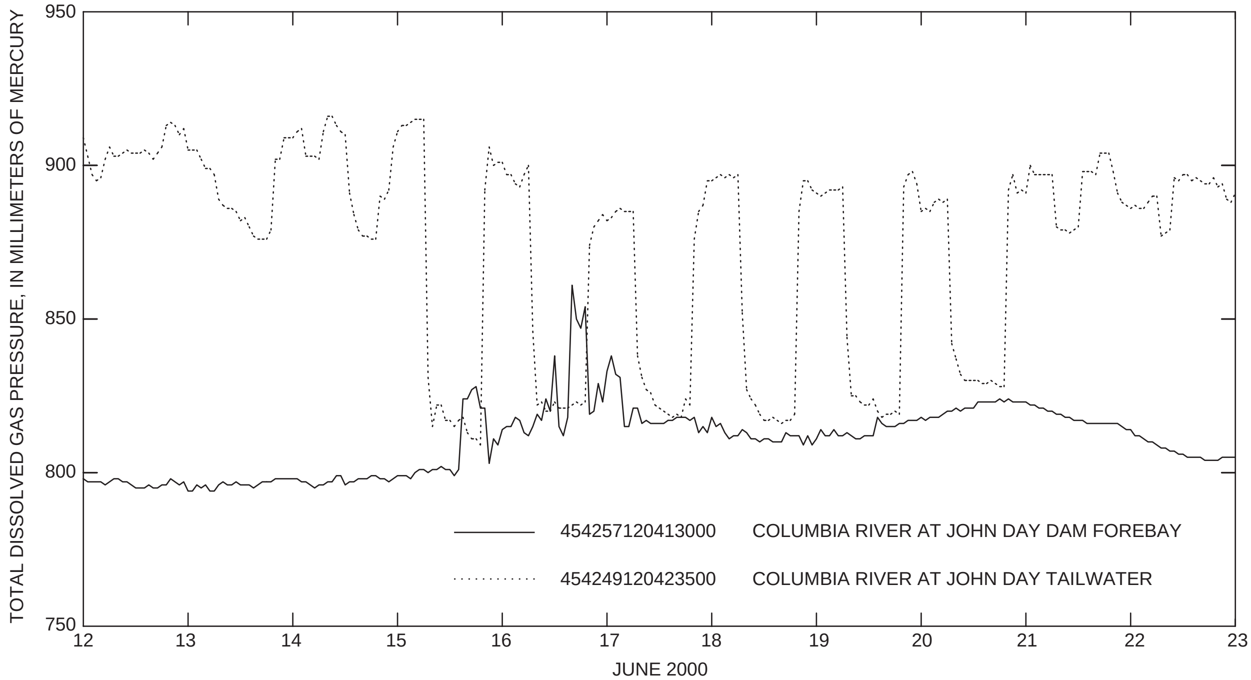


Figure 10. Total dissolved gas pressure above and below John Day Dam**.**

TOTAL DISSOLVED GAS REPORT FOR JOHN DAY TAILWATER
starting at 0405 22 jun 2000

DATE	TIME	WA TM DEG F	BARO PRES	TD1 GAS PRES	TD2 GAS PRES	GAS(1) %	SPILL S	TOT R
0622	0500	62.7	760.0	897.0	890.0	118.03	090.4	153.5
0622	0600	62.7	759.0	897.0	888.0	118.18	083.4	147.6
0622	0700	62.7	760.0	880.0	879.0	115.79	054.3	160.6
0622	0800	62.7	760,0	879.0	875.0	115.66	054.2	176.7
0622	0900	62.8	761.0	879.0	874.0	115.5l	054.2	181.7
0622	1000	62.8	761.0	878.0	873.0	115.37	054.3	185.8
0622	1100	62.8	759.0	879.0	873.0	115.81	058.7	194.9
0622	1200	62.9	760.0	880.0	873.0	115.79	063.9	211.7
0622	1300	62.9	759.0	898.0	887.0	118.31	070.3	230.4
0622	1400	63.0	759.0	898.0	892.0	118.31	070.3	264.1
0622	1500	63.1	760.0	898.0	891.0	118.16	070.5	236.0
0622	1600	63.1	760.0	897:0	891.0	118.03	073.4	235.0
0622	1700	63.1	759.0	904.0	896.0	119.10	081.4	275.8
0622	1800	63.1	760.0	904.0	896.0	118.95	083.0	274.7
0622	1900	63.1	759.0	904.0	895.0	119.10	084.0	264.4
0622	2000	63.1	760.0	898.0	891.0	118.16	136.8	233.5
0622	2100	63.2	761.0	891.0	882.0	117.08	122.2	209.8
0622	2200	63.2	761.0	888.0	880.0	116.69	122.2	207.2
0622	2300	63.1	759.0	887.0	878.0	116.86	124.5	206.8
0623	000	63.1	761.0	886.0	880.0	116.43	122.1	203.0
0623	0100	63.1	760.0	887.0	880.0	116.71	122.1	200.4
0623	0200	M	M	M	M	U	118.3	190.7
0623	0300	M	M	M	M	U	118.3	200.2
0623	0400	M	M	M	M	U	116.4	200.4

STATUS=M, data missing due to lag time between data collection and transmission
STATUS=U, data unavailable (not calculable)

Figure 11. Example data table from U.S. Army Corps of Engineers Total Dissolved Gas Reports Web page (http://www.nwd-wc.usace.army.mil/report/tdg.htm).

due to low battery voltage. The recorded probe depth was also graphed. E-mail correspondence referring to each site was also archived in the corresponding site folder.

SUMMARY OF DATA COMPLETENESS AND QUALITY

Year-end summaries of water year 2000 TDG data completeness and quality are shown in table 2. Data in this table were based on the amount of hourly TDG data and barometric pressure data that could have been collected during the scheduled monitoring season. At all stations, more data were collected than was scheduled because the monitors were set up early to ensure correct operation. Because TDG in percent saturation is calculated as total dissolved gas pressure, in millimeters of mercury, divided by the barometric pressure, in millimeters of mercury, multiplied by 100 percent, any hour with missing TDG pressure data or missing barometric pressure data was counted as an hour of missing data for TDG in percent saturation. The percentage of real-time data received shown in table 2 represents the data that were received via satellite telemetry at the USGS downlink. The USACE downlink operated independently, but the amount and quality of the data were very similar. At each station, 98 percent or more of the data were received real-time by the USGS downlink, with an overall average of 99.6 percent. Problems with the amount of real-time data received were usually due to malfunction or misprogramming of the data-collection platform.

The collection of water temperature data had fewer complications than did the collection of TDG and barometric pressure data. There were only a few hours of missing or incorrect temperature data, except for instances where all data parameters were missing due to problems with the DCP.

TDG data were considered to meet quality-assurance standards if they were within 1 percent TDG of the expected value, based on calibration data and ambient river conditions at adjacent sites. The percentage of real-time TDG data passing quality assurance is shown in table 2. The lowest percentage for a station was 95.3 percent at Skamania, but all of the missing data was eventually restored to the database. The overall average of real-time data passing quality-assurance standards was 98.5 percent. Most problems with meeting quality-assurance standards were due to membrane failure—leaking or tearing of the TDG membrane.

QUALITY-ASSURANCE DATA

Duplicate data for John Day tailwater were collected for TDG only. Data between the two instruments compared well, as depicted on figure 12, which shows how the two probes responded to daily changes in spill at the John Day Dam. The greatest differences occurred at times when gas levels changed rapidly, as a

Table 2. Total dissolved gas data completeness and quality, water year 2000
[TDG, total dissolved gas]

Abbreviated station name	Planned monitoring, in hours	Percentage of real-time TDG data received	Percentage of real-time TDG data passing quality assurance
John Day forebay	4,032	99.4	99.4
John Day tailwater			
Main probe	4,032	99.9	99.9
Duplicate probe	4,032	99.9	98.7
The Dalles forebay	4,032	99.5	97.7
The Dalles tailwater	4,032	100.0	100.0
Bonneville forebay	8,784	98.3	98.2
Skamania	4,560	100.0	95.3
Warrendale	8,784	99.9	99.3
Camas	4,560	99.8	98.0
Average		**99.6**	**98.5**

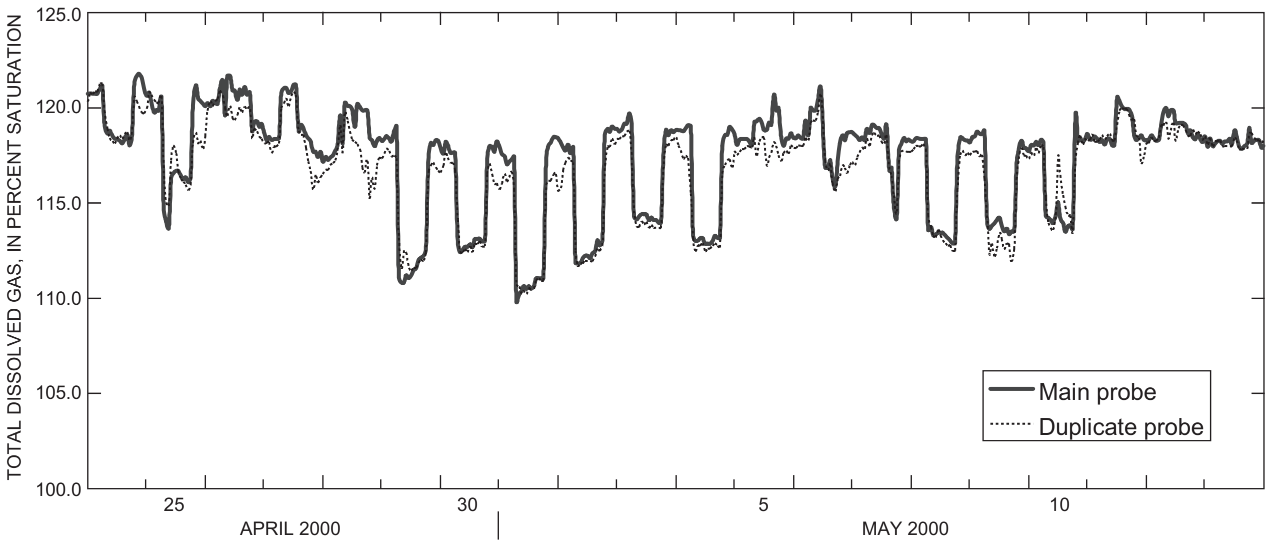


Figure 12. Selected total dissolved gas data at the main and duplicate probes at John Day tailwater.

result of each probe responding at a different rate. Future deployment of redundant probes should have paired membranes with the same age and use, to reduce differences in response time.

A slight bias existed between the two probes as depicted by figure 13, which represents 4,317 hourly values from March 23 to September 18, 2000. The duplicate probe was 1 foot higher in the water column and tended to read lower than the main probe. A likely cause of this bias may be a reduced flow over the membrane on the duplicate probe. Perforations in the housing were originally intended for one probe located at the end of the housing. This concern will be eliminated by installing two adjacent TDG sensors on the same Hydrolab.

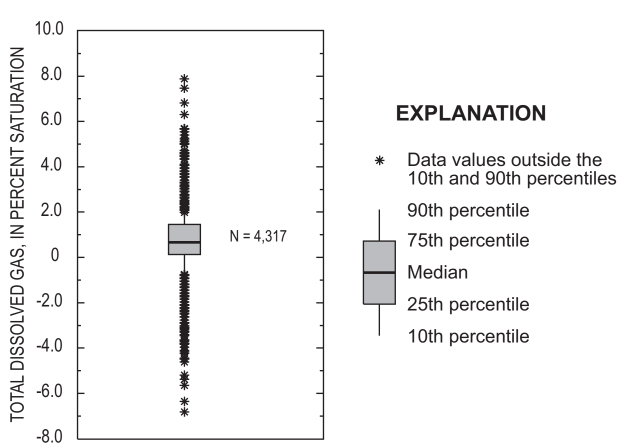


Figure 13. All of the total dissolved gas data at the main and duplicate probes at John Day tailwater.

Duplicate TDG and water temperature data were collected at the John Day forebay from 4/5/2000 at 1600 hours to 4/12/2000 at 1400 hours. The duplicate probe was mounted approximately 6 feet horizontally from the main probe at the same depth. The duplicate data were collected to confirm the rapid changes in temperature and TDG above the John Day Dam that did not occur below the dam, as depicted in figures 14 and 15. TDG and water temperature measured by the main probe compared well with the duplicate probe. Based on the strong correlation between the two units, the rapid changes in water temperature and TDG appear to be real and not a problem with instrumentation. The cause of these rapid changes is not known at this time; however, it is suspected that water near the probes is not well mixed and occasionally water in the vertical section is transported across the face of the dam by certain spill patterns that cause poorly mixed water to flow over the probes.

SITE-SPECIFIC CONSIDERATIONS

Even though the same type of electronic equipment and instruments were used at each site, there were differences among the sites in the physical setup and environment of equipment. Some sites were at a river location with limited depth, some had greater circulation of water past the probe, and some were prone to damage by insects. These site-specific considerations are summarized below for each of the eight sites.

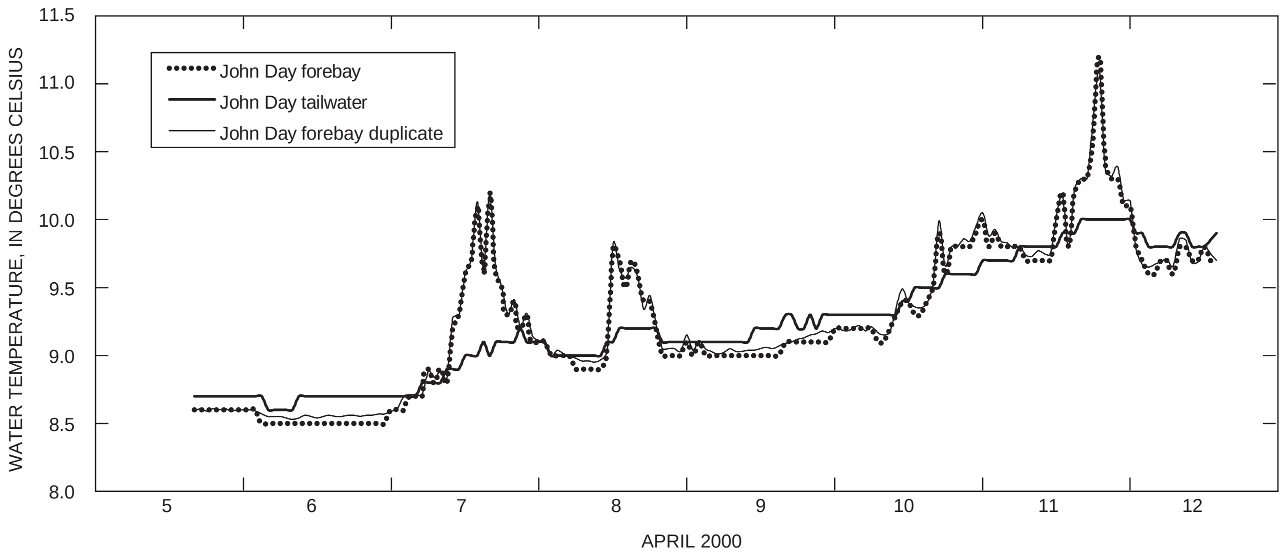


Figure 14. Duplicate water temperature data at John Day forebay and water temperature data at John Day tailwater.

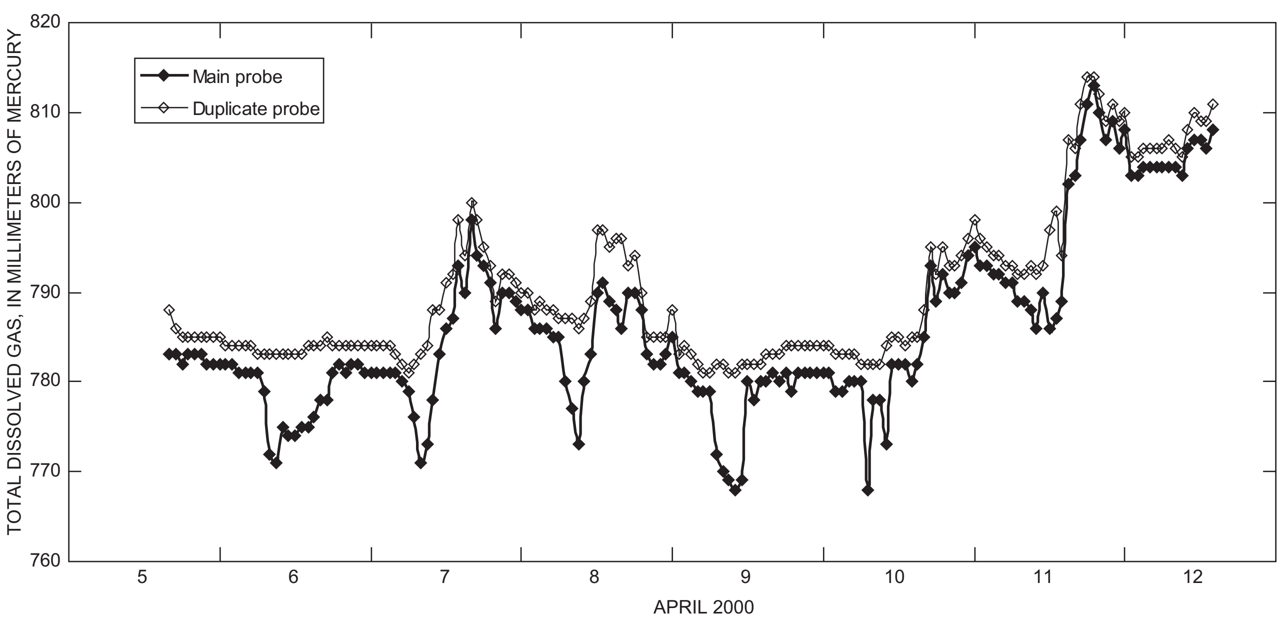


Figure 15. Duplicate total dissolved gas data at John Day forebay.

Camas

At the Camas site, there were three separate occasions (June 29, July 23, and July 31, 2000) when the TDG membrane was pierced by aquatic insects, which were observed inside the probe housing. When this happened, the hole in the membrane allowed water pressure instead of dissolved gas pressure to act on the TDG pressure sensor. As a result, the measured values for TDG rose suddenly to about 1,000 mm Hg, even though there was not an unusual amount of spill from Bonneville Dam, which is upstream of the Camas site. This condition was diagnostic of a broken membrane, and accordingly, an emergency field trip was made to replace the probe with a newly calibrated probe. During the third trip due to a damaged membrane, screening was added to the probe to exclude insects, and the problem did not reoccur. TDG data that were lost due to this type of damage were not recoverable because there is no way to know precisely what would have been recorded at those times.

Also at the Camas site, the barometer was adjusted incorrectly, resulting in a bias of -5 mm Hg for 21 hours beginning on June 5, 2000, at 1200 hours. The barometer was readjusted, and the 21 hours of data were corrected in the database.

Skamania

At Skamania, a newly calibrated probe was placed in the river on August 30, 2000, at 1036 hours. The following day, scheduled spill ended for the season at Bonneville Dam, just upstream. As a result, the TDG was expected to decrease at the Skamania site, and a decrease was observed. However, the TDG eventually decreased to levels lower than would be expected. When the probe was inspected, it was found to have a faulty sensor, which accounted for the TDG readings being too low. Subsequently, a linear shift was applied to the data, with no shift for August 30 at 1100 hours, and shifts increasing until a final shift of +56 mm Hg on September 18 at 1100 hours. This was an example of data being transmitted in a real-time manner, but not being correct. Further, in this case, the data were correctable because the gradual decline in TDG readings (with no change in spill) was consistent with a gradually failing TDG sensor.

Warrendale

At Warrendale, there was a faulty TDG sensor, which resulted in erratic TDG values from February 29, 2000, at 1300 hours until March 2, 2000, at 0800 hours. The sensor was replaced, but there was no way to correct the data in question, so it was deleted from the database.

Compensation depth for TDG measurement is the depth above which degassing will occur. In order to measure TDG accurately, the probe must be deeper than the compensation depth, which is calculated as [TDG pressure, in millimeters of mercury, minus barometric pressure, in millimeters of mercury] divided by 23 (a constant). This equation was based on a formula derived from Colt (1984, page 104). If the probe is above the minimum compensation depth, the measured TDG may be less than it would be if measured at a greater depth.

The compensation depth can be calculated for any given percent saturation of TDG if an assumption is made for the barometric pressure. For example, if the barometric pressure is assumed to be 760 mm Hg, and the TDG level is 120%, the TDG pressure would be 912 mm Hg (120% of 760 mm Hg), and the compensation depth would be [912 - 760]/23 = 6.6 feet. Using the same assumption for barometric pressure, at a TDG level of 145%, the compensation depth would be 14.9 feet. Where possible, the TDG probes were kept at a depth of 15 feet or greater.

Warrendale was the only site where the TDG probe was above the compensation depth at any time in water year 2000. After the end of the spill on August 31, 2000, the river stage had dropped, but supersaturated water remained in the river from upstream dams, resulting in the probe depth being above the compensation depth for several days (fig. 16). This was because of the physical characteristics of the site. The instruments were housed on a floating wooden dock, and the TDG probe was suspended from the dock. When the river was shallow at the Warrendale site, as it was in early September, the probe depth was about 4 feet because that was the total depth of the river below the dock at the time. In order to measure TDG at a greater depth, the probe would need to be moved to a deeper part of the river, but that was not possible because of the fixed location of the site.

Bonneville

At the Bonneville site, there were data transmission problems from January 1 to January 5, 2000, resulting in 46 hours of missing real-time TDG data. The cause of this missing data is unknown, but it may have been due to large cranes that work in the dam area, which have been known to sometimes be placed between the DCP antenna and the orbiting satellite, thus occluding the satellite. These 46 hours of TDG data were restored to the permanent database using the data logged onsite by the DCP.

From July 21 to July 25, 2000, 91 hours of data were missing from the Bonneville site due to failure of the DCP. In this case, the data were not logged onsite, so it was not possible to restore the data to the database.

The Dalles Tailwater

Only 2 hours of TDG data were missing from The Dalles tailwater site. One datum was missing due to calibration activities on July 20, 2000, and the cause of loss of the other datum is not known.

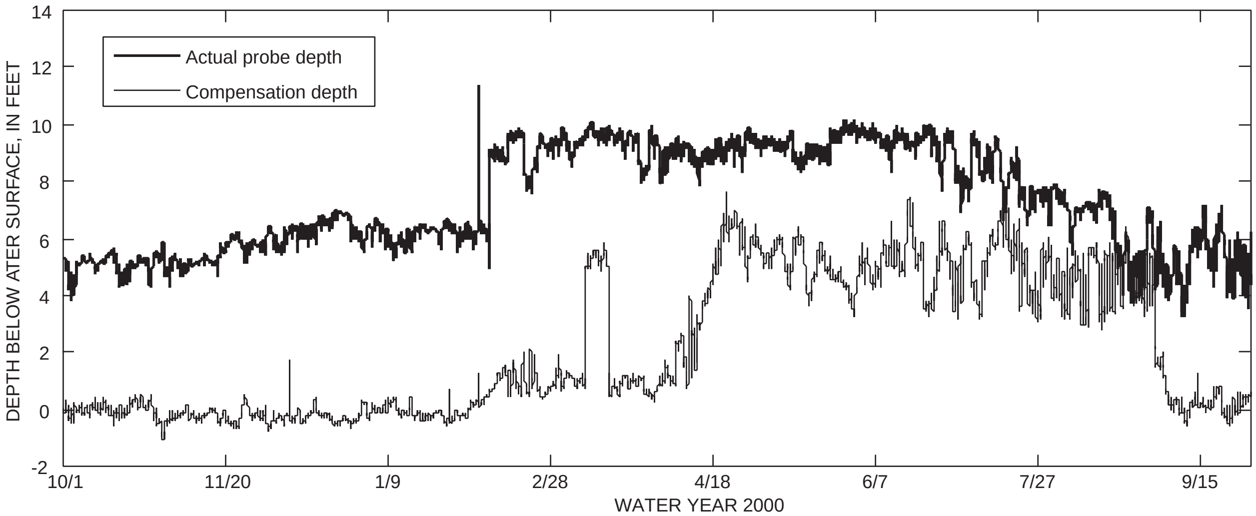


Figure 16. Compensation depth and actual probe depth at Warrendale.

The probe housing at The Dalles tailwater site is strapped to anchors along a slope of rock rip-rap. On several occasions during the monitoring season, the probe housing was raised or lowered according to the river stage. In this manner, it was possible to maintain the probe depth below the minimum compensation depth.

The Dalles Forebay

TDG data were missing from The Dalles forebay site for a 72-hour period from April 15 to April 18, 2000, due to a ruptured TDG membrane. It was not possible to restore these data to the database.

DCP problems from August 29 to September 5, 2000, were the cause of 19 hours of data that were missing in real-time. These data were later restored to the database from the data logged onsite by the DCP.

John Day Tailwater

For the duplicate unit at the John Day tailwater site, 45 hours of TDG data were missing from September 4 to September 6, 2000, due to a rupture or tear in the TDG membrane. These data could not be restored. There were only 3 hours of missing TDG data for the main unit at John Day tailwater.

John Day Forebay

Beginning on August 3, 2000, 23 hours of TDG data were missing from the John Day forebay site due to an error in reconnecting the electronic barometer during a routine calibration. These data could not be restored to the database.

On several occasions at the John Day forebay, the TDG value was observed to suddenly rise 10 or 20 mm Hg for several hours for no apparent reason. It was noted that the water temperature also rose during these times. These excursions of TDG and water temperature were observed on hot, sunny days, and it is believed that a parcel of heated water was drawn past the submerged TDG probe during spill, causing the increase in water temperature. The TDG measured at the probe would be expected to also increase, because when a gas is heated and the volume is fixed (as it is inside the TDG membrane), the pressure of the gas will increase.

REFERENCES CITED

Colt, J. 1984. Computation of dissolved gas concentrations in water as functions of temperature, salinity, and pressure: American Fisheries Society Special Publication 14, 154 p.

Jones, J.C., Tracey, D.C., and Sorensen, F.W., eds., 1991, Operating manual for the U.S. Geological Survey's data-collection system with the Geostationary Operational Environmental Satellite: U.S. Geological Survey Open-File Report 91–99, 237 p.

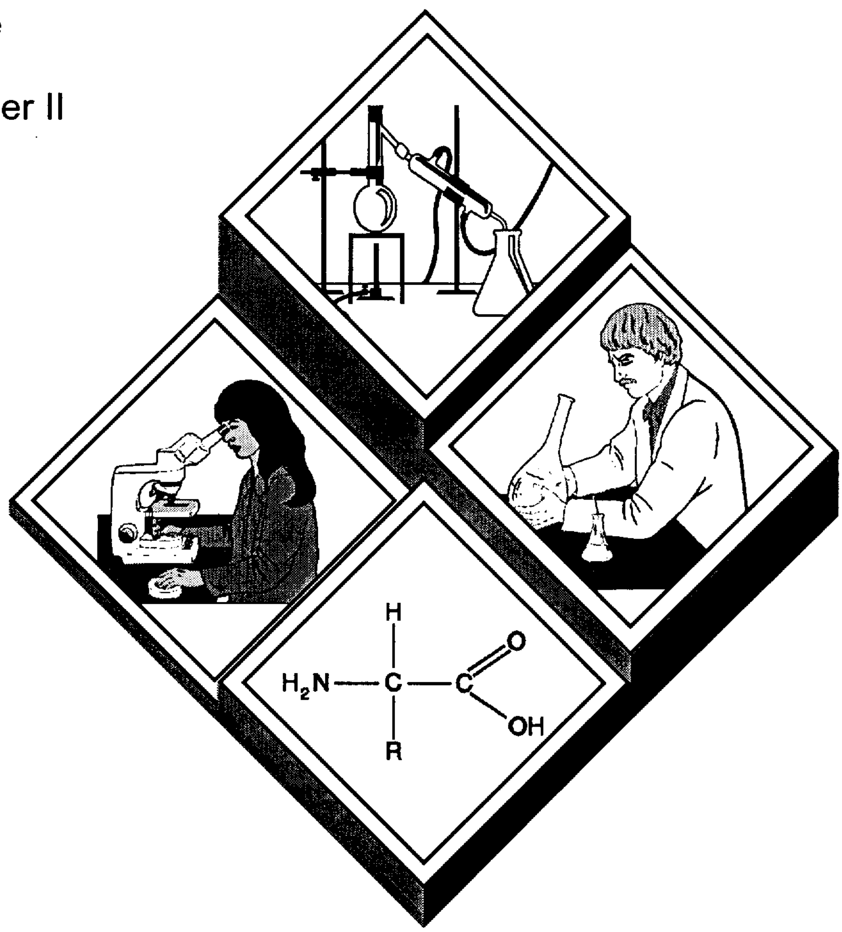
Tanner, D.Q., Harrison, H.E., and McKenzie, S.W., 1996, Total dissolved gas, barometric pressure, and water temperature data, lower Columbia River, Oregon and Washington, 1996: U.S. Geological Survey Open-File Report 96–662A, 85 p.

U.S. Environmental Protection Agency, 1986, Quality criteria for water: Washington, D.C., EPA–440–5–86–001.

US Army Corps
of Engineers®
Walla Walla District

Quality Assurance and Quality Control for Total Dissolved Gas Monitoring - Lower Snake River, Washington; Clearwater River, Idaho; and Columbia River, Oregon and Washington, 2000

Authors:
Russell D. Heaton III
Timothy Seiple
Gary Slack
Thomas D. Miller II



February 2001

QUALITY ASSURANCE AND QUALITY CONTROL FOR TOTAL DISSOLVED GAS MONITORING - LOWER SNAKE RIVER, WASHINGTON; CLEARWATER RIVER, IDAHO; AND COLUMBIA RIVER, OREGON AND WASHINGTON

February 2001

Authors:

Russell D. Heaton III
Timothy Seiple
Gary Slack
Thomas D. Miller II

TABLE OF CONTENTS

APPENDIXES

LIST OF FIGURES

TABLE OF CONTENTS (continued)

LIST OF FIGURES (continued)

LIST OF TABLES

QUALITY ASSURANCE AND QUALITY CONTROL FOR TOTAL DISSOLVED GAS MONITORING - LOWER SNAKE RIVER, WASHINGTON; CLEARWATER RIVER, IDAHO; AND COLUMBIA RIVER, OREGON AND WASHINGTON FEBRUARY 2000

Russell D. Heaton III
Timothy Seiple
Gary Slack
and
Thomas D. Miller II

ABSTRACT

The U.S. Army Corps of Engineers Walla Walla District (CENWW) operates 16 monitoring stations for monitoring total dissolved gas (TDG) in the Columbia, Snake, and Clearwater Rivers. Each station transmits this hourly data via the Geo-stationary Operational Environmental Satellite (GOES) system every 4 hours to the Corps of Engineers Northwestern Division (CENWD) in Portland, Oregon. The data is stored in the Columbia River Operational Hydromet Management System (CROHMS) database. In Fiscal Year (FY) 2000, the district [with cooperation from HDR Engineering and the United States Geological Survey (USGS) in Pasco, Washington] installed improved equipment and new data collection platforms (DCP's). This year's focus was on maximizing sonde reliability and precision. A rigorous Quality Assurance/Quality Control (QA/QC) program was initiated to determine the absolute precision of measurement and repeatability using Hydrolab Minisonde water quality sondes. The data quality objectives (DQO's) for the instruments were set at ±2 millimeters of Mercury (mm Hg) for dissolved gas pressure and ±0.2 degrees Celsius (° C) for temperature. The instrument inventory mean was calculated to be 0.25 mm Hg with a standard deviation variation (SDV) of 1.11 for gas pressure and -0.04° C with an SDV of 0.07. Improved calibration procedures and new standards accounted for the increases in accuracy. Evaluation of the performance of each field station proved far more difficult. The monthly charting processes proved to be more valuable to evaluate the problems as they occurred rather than for pure statistical use. Included in this report are the individual 28 sonde performance histories for water year 2000 and each station performance description, including the monthly charts. Appendix B includes the pertinent quality data used to produce this report and appendix F provides high detail maps produced from 7.5-minute quad sheets with pinpoint locations of each TDG monitoring site.

INTRODUCTION

The CENWW operates six multi-purpose dams in the Columbia River, Lower Snake River, and Clearwater River Basins. These facilities cover a total calculated drainage area of over 214,000 square miles of the Pacific Northwest and provide flood control, navigation, irrigation, recreation, hydropower, fish and wildlife habitat, and municipal and industrial water supply. During spring runoff, air is entrained with plunging flows over the spillways and is carried deep into the spillway's stilling basin where water pressure causes the air to dissolve. Beyond the stilling basin, the river becomes shallow and the water becomes supersaturated. The U.S. Environmental Protection Agency (USEPA) has established an upper limit of 110 percent saturation for protection of freshwater aquatic life. Concentrations above this level can cause gas bubble trauma in fish and adversely affect other aquatic organisms (USEPA, 1986). Spillway deflectors have been installed on all dams in the area served by CENWW to reduce the plunging depths of spillway flows during normal water years. The Corps minimizes spring stream flows in the region to reduce the production of TDG and to save water for summer needs. The CENWW collects real-time TDG data (available within about 4 hours of current time) upstream and downstream from its dams in a network of fixed station monitors known as the Total Dissolved Gas Monitoring System (TDGMS).

Background.

Real-time TDG data are vital for dam operation and for monitoring compliance within state and Federal guidelines and regulations. The data is used by water management personnel from the Walla Walla and

Portland offices of CENWD to maintain favorable water quality conditions, facilitate fish passage, and improve survival in the Federal Hydropower System. HDR Engineering (HDR), under contract DACW-00-D-001 with CENWW, collected hourly TDG and related data in the Mid-Columbia, Lower Snake, and Clearwater Rivers from 16 TDGMS sites. Since 1996, CENWW has maintained a data collection system with increasing levels of QA and QC. In conjunction with HDR, they provided most of the technical innovation currently used by all Federal, state, and local entities. However, data collection methods and QA plans have changed significantly since 1996. In water year 2000, improved TDG/temperature probes and new methods of calibration in the laboratory were used. In addition, hourly data for water year 2000 were corrected or deleted to reflect measurements made during instrument calibration.

Purpose and Scope.

The purpose of gas monitoring is to provide managers, agencies, and interested parties with near real-time data for managing stream flows and TDG levels downstream from Federal dams. As with any data collection activity, an important component that cannot be overlooked is the quality of the data. Measurement of data quality allows determination of the usefulness and relevance to their current and future decision processes. This report describes the data collection methods and evaluates QA data for the TDGMS that includes the McNary, Ice harbor, Lower Monumental, Little Goose, and Lower Granite reservoirs. Additionally, this system provides water quality data for the Clearwater River downstream of Dworshak Dam, the Columbia River near Pasco, and the Snake River near Anatone, Washington (see figure 1 and table 1). This report is designed to document data quality of the TDGMS for water year 2000. Measurements include TDG pressure, barometric pressure, and water temperature at 16 sites.

Acknowledgments.

We wish to acknowledge the aid and support of Mr. Wayne John, the chief of Operations Division in Walla Walla District, U.S. Army Corps of Engineers. Our thanks go to Mr. Dave Reese, chief of Hydrology Section, for his technical and logistical support of this evaluation. The authors also acknowledge Mr. Greg Ruppert, Mr. Andy Records, Mr. Joe Bunt, and Mr. Dwight Tanner, our co-operators from the USGS, for assistance in operation of the DCP's. Thanks go to Ms. Ruth Abney for keeping the focus throughout all the turbulence of a new millennium. And our very special thanks go to Mrs. Julie Dockery and Mrs. Charlene Duncan, those special ladies who issue the contracts to fuel our scientific endeavors.

METHODS

Instrumentation.

Instrumentation at each fixed station consists of a multi-parameter water quality sonde, an electronic barometer, a DCP, and either a 120 volt alternating current (VAC) or 12 volt direct current (VDC) power supply. The water quality sonde currently in use is the Hydrolab® Corporation Minisonde® 4 or Minisonde 4a. The sonde has individual sensors for TDG, temperature, and dissolved oxygen (DO). The TDG sensor membrane consists of a cylindrical framework wound with a length of Silastic (dimethyl silicon) tubing. The tubing is tied off at one end and the other end is connected to a mechanical pressure transducer. After the TDG pressure in the river equilibrates with the gas pressure inside the tubing (about 15 to 20 minutes), the pressure transducer measures a potentiometric voltage that is converted to mm Hg electronically. Thus, a point measurement of the TDG pressure in the river is then transmitted digitally to the DCP. The water temperature sensor is a thermocouple. The barometer was manufactured by Honeywell and is a PPT model [14 pounds per square inch (psi)] precision pressure transducer connected to analog channel 4 on the DCP. The sonde is connected by a heavy-duty, weatherproof cable into the SDI-12 channel of a Sutron® Model 8210 DCP. The DCP has three basic functions: sensor interfacing, data storage, and data transmission to the GOES system (Jones et al., 1991). Most of the stations use a crossed Yagi antenna connected to the DCP using a coaxial cable with the antenna mounted on a mast to provide transmission to the GOES system. Due to continuous vandalism problems at the Pasco levee and McNary tailwater stations, a "Top-hat" antenna is used.

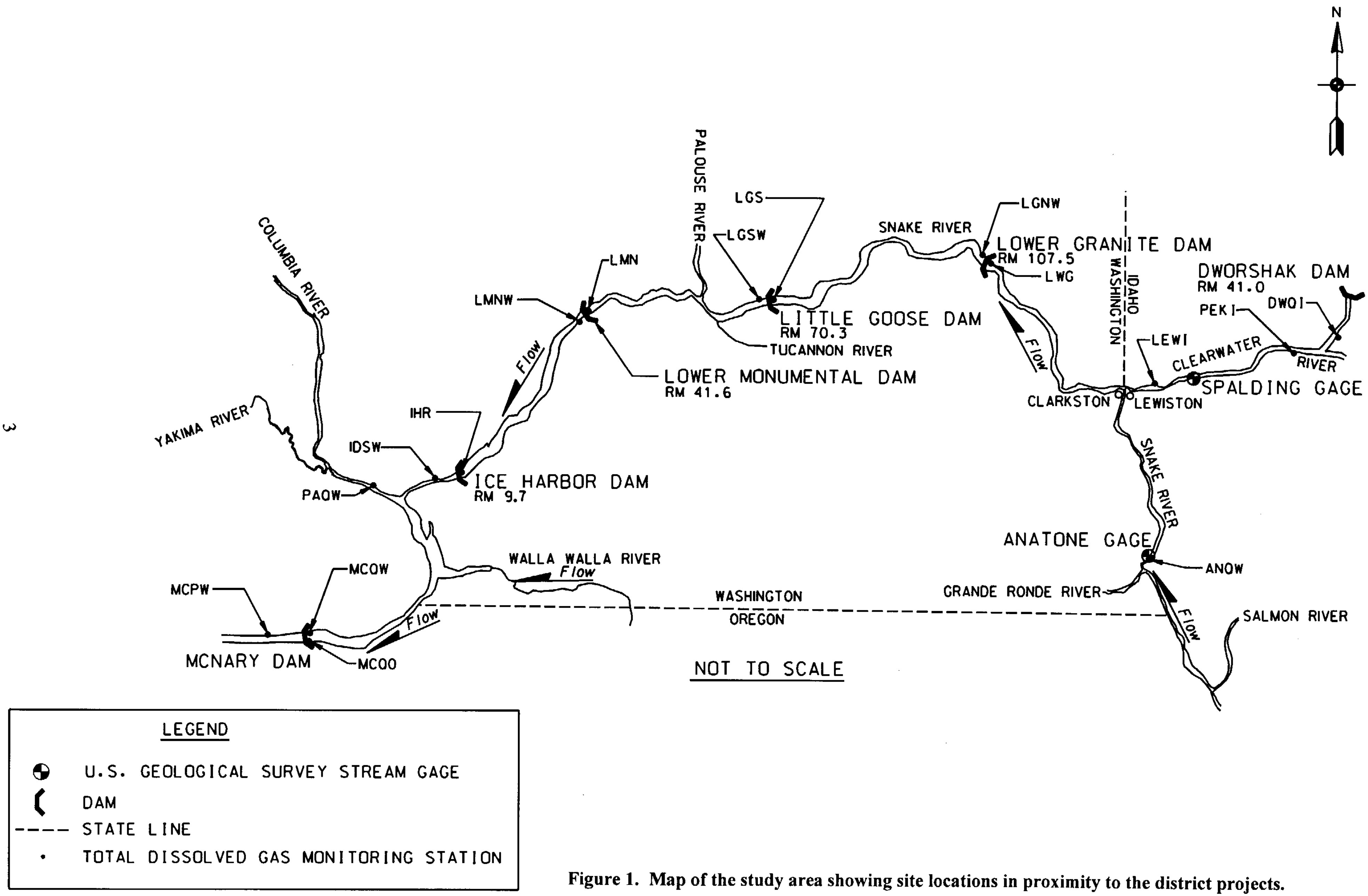


Figure 1. Map of the study area showing site locations in proximity to the district projects.

Station Letters	Date Est	River Name	River Mile	Description	Latitude	Longitude	Project	Drainage Area	Quad Map Name
ANQW	1998	Snake River	167.5	Left Bank	460550	1165836	LWG	92,960 sqm	Limekiln Rapids, Idaho
DWQI	1994	NF Clearwater River	40	Left Bank	463011	1161918	DWR	2,440 sqm	Ahsahka, Idaho
IDSW	1990	Snake River	6	Right Bank	431432	1185620	IHR	109,000 sqm	Humorist, Washington
IHR	1984	Snake River	10	Mid-River	461458	1185242	IHR	109,000 sqm	Levey SW, Levey, & Slater Washington
LEWI	1996	Clearwater River	4	Right Bank	462606	1165736		93,400 sqm	Lewiston Orchard North, Idaho
LGNW	1990	Snake River	107	Right Bank	463958	1172618	LWG	103,500 sqm	Almota, Washington
LGS	1984	Snake River	70	Mid-River	463505	1180132	LGS	103,900 sqm	Starbuck East, Washington
LGSW	1990	Snake River	69	Right Bank	463459	1180231	LGS	103,900 sqm	Starbuck East, Washington
LMN	1984	Snake River	42	Mid-River	463347	1183214	LMN	108,500 sqm	Lower Monumental Dam, Washington
LMNW	1990	Snake River	41	Left Bank	463313	1183251	LMN	108,500 sqm	Lower Monumental Dam, Washington
LWG	1984	Snake River	108	Left Bank	463933	1172530	LWG	103,500 sqm	Almota, Washington
MCPW	1990	Columbia River	291	Right Bank	455600	1191930	MCN	214,000 sqm	Umatilla, Oregon-Washington
MCQO	1986	Columbia River	292	Left Bank	455558	1191743	MCN	214,000 sqm	Umatilla, Oregon-Washington
MCQW	1985	Columbia River	292	Right Bank	455625	1191747	MCN	214,000 sqm	Umatilla, Oregon-Washington
PAQW	1998	Columbia River		Left Bank	461332	1190725	MCN	103,000 sqm	Pasco, Washington
PEKI	1996	Clearwater River	36	Left Bank	463226	1162331	DWR	8,040 sqm	Southwick, Idaho

Table 1. Description and Locations table of the 16 TDGMS stations.

At all 16 stations, the DCP controls the supply of power to the barometer and the water quality sonde. All DCP's are powered directly by an 86 ampere-hour, 12-volt gelled-electrolyte battery manufactured by Deka®. The battery was charged by a regulated voltage circuit from a 12 VDC, 30-watt solar panel regulated by a Sunsaver® model (6 or 10) LVD power controller or a 120 VAC trickle charge system manufactured by Coastal Environmental Systems®. The DCP is programmed to record and transmit five parameters: barometric pressure (in mm Hg), TDG pressure (in mm Hg), DO [in milligrams per liter (mg/L) and % saturation], water temperature (in ° C), and battery voltage (in volts). Battery voltage is monitored to ensure that the instrumentation receives adequate power. The data for each parameter is logged electronically every hour, on the hour, and stored in the DCP memory. Every 4 hours, the DCP transmits the most recent 8 hours of logged data to the GOES satellite. Consequently, each piece of data is transmitted three times to protect against data loss. The GOES satellite retransmits the data to a direct readout ground station at Wallops Island where it is automatically decoded and retransmitted to the DOMSAT system. A satellite downlink automatically transfers the data to the CROHMS database located in Portland, Oregon. During the fixed station calibration visits, the DCP stored data can be downloaded to a Rocky 2000® computer. When it is necessary to fill in any real-time data lost during satellite transmission, data is sent via e-mail to our division office in Portland, Oregon.

The same type of instrumentation was used at each of these 16 stations but installations, locations, and river conditions near the instruments differed according to site. Notably, stations above and below dams recorded either slow-moving stratified water or well-mixed higher-velocity water. In all cases, stations were subject to daily fluctuations in river flow as turbines and spillway gates were periodically opened and closed.

Each instrument package is installed in a 4-inch-diameter PVC pipe mounted in a convenient but unobtrusive location. Forebay stations are attached to the face of the dam by clamps. Tailwater and river stations are laid on the bank and anchored to large blocks of concrete a few feet below water. The instrument is inserted and withdrawn by use of a small rope looped over a bolt at the submerged end of the pipe. This usually works well but, occasionally, river debris, mechanical damage, or fluctuating water levels interfere with normal operation.

The Dworshak tailwater station has a dual communications package and is configured to send 15-minute data to the powerplant operator to assist in operation of the Francis turbine air injection system. The data is then sent through the GOES systems on the 4-hour time hack with hourly data like the rest of the DCP's. The special 15-minute data is sent directly to the powerplant operator controls and is not available for outside use beyond the project control room.

Calibration of Instruments in the Laboratory.

Active sondes are calibrated on a 2-week cycle. The general procedure is to check the operation of the probe deployed at the station without disturbing it, replace the in-place probe with one recently calibrated in the laboratory (QA/QC probe), and then to check the operation of the newly deployed probe. The details of the laboratory calibration procedures are as follows.

The TDG sensor requires an actual two-step calibration procedure. This means that adjustments are made at two intervals in the calibration curve in order to calibrate the sensor. The base calibration point is referred to as Base TDG and the pressurized calibration point corresponding to pressurized TDG pressure. For TDG sensor calibration, the base point is equal to the atmospheric pressure at the time of calibration as measured by a weather service type, wall-mounted mercury barometer. The pressure point is equal to the barometric pressure plus a standard value that is chosen to create a calibration curve with a range that will include the range of TDG values expected to be measured in the field by the sensor. In most cases, the pressure point is equal to the barometric pressure plus 200 or 300 mm Hg. This creates a slope capable of interpolating the full range of expected field values. Pressure calibrations were done using a Hiese® digital pressure calibrator, which is certified according to standards of the National Institute of Standards and Technology (NIST). The end of the TDG probe containing the sensors was put in a plastic pressure chamber and the pressure was increased 200 mm Hg above the ambient barometric pressure.

The TDG membrane is cleaned with a squirt bottle of tap water then tested for leaks using soda water. If the membrane does not have a leak, it is removed from the sensor and air-dried for at least 72 hours. The TDG sensor is also air-dried at room temperature for at least 24 hours since water sometimes collects inside the tubular membrane due to condensation. If the condensation is not removed, it can slow the equilibration of air pressure between the outside of the membrane and the TDG sensor.

Each sonde contains a thermister for recording and reporting water temperature. The results are reported in ° C. Sonde thermisters are all factory calibrated. We do not make adjustments to the temperature sensor calibration. Therefore, the only measure thermister performance was by comparing the reading to an approved National Biological Survey (NBS) mercury thermometer standard. Sondes with thermisters that proved to be errant or erratic in performance were taken out of the active inventory and shipped to the manufacturer for repair and calibration.

A DO probe measures the amount of oxygen present in water and is used by the system operators to make quality checks on the data and as a surrogate to measure instrument competency. The Sonde reports the DO results in percent (%) and mg/L. The method for calibrating the DO sensors has not yet been selected for the standard operating procedures (SOP's), but instruments are calibrated every 2 weeks using the manufacturer's published procedures. In most cases, the calibration is conducted using saturated air or azide modified Winkler titration.

Barometric pressure is used as a standard for calibrating the TDG and DO sensors. It is also an important value used in calculating the percent of TDG saturation. HDR maintains performance records for the wall-mounted mercury barometer located at HDR, the Surveyor 4 instrument used for fieldwork, and the Honeywell barometers at each station. Calibration data is also maintained for the Surveyor 4, which is the only barometric pressure-sensing device that can be calibrated by our personnel.

Performance Data.

It is important to recognize the difference between calibration data and performance data. *Performance Data* is collected each time a sensor is compared to its standard or when two instruments are compared at a given station. These values represent the measured difference between two readings and are keyed with the term *Delta.* Delta values mirror the ± variation of sensor or instrument readings from their respective standard. For example, a negative value indicates that the sensor or instrument was reading below its respective standard. Appendix A contains an example of the data entry form used to make QA/QC calculations.

Calibration Data.

Calibration procedures only take place after recording the performance data described above. *Calibration Data* reflects the actual adjustments that take place when a sensor is calibrated to correct for drift. These values are keyed with the term *Adjustment* because they represent an actual adjustment to the calibration curve. A positive adjustment indicates that the sensor was reading below the standard (equivalent to a negative performance value) and required a positive adjustment. Adjustment and Delta values will always have opposite signs but should be the same number. The datasheets used in collecting the QA/QC information and used to document the calibration measure were then put into the ACCESS database for the calculations and compilation of the QA/QC reports.

System- and Inventory-Wide Charting and Calculations.

Each month, the data collected from all of the stations are combined to evaluate "System-Wide Station Performance." Likewise, all of the instrument data points collected in a single month are combined to evaluate the "Inventory-Wide Sonde Performance." This allows us to see if the control limits are being met and gives us the opportunity to identify trends in the data that may indicate possible problems in the system that may not be apparent when looking at an individual data point. If the signature of a previously encountered problem can be identified, preventive measures can be taken to resolve the issue and avoid a potential system audit.

Monthly sonde charts evaluate the *performance* data for the entire population of TDG sensors and thermometers, combined. Delta values are calculated for each parameter by subtracting the appropriate standard from the observed pre-calibrated sensor reading collected during instrument calibration. Once the delta values are calculated, they are averaged on a monthly basis to calculate a monthly mean delta value for each parameter. The standard deviation is also calculated for each parameter on a monthly basis. The following equations summarize the above description.

Delta Base TDG = **[Pre-Calibrated Base TDG] - [Atmospheric Pressure]**
Delta Pressure TDG = **[Pre-Calibrated Pres. TDG] - [Pressurized Standard]**
Delta Temperature = **[Sonde Temperature] - [NBS Standard Temperature]**
Monthly Mean Delta for parameter X
= **[Sum of Deltas for X] / [n] where n = number of delta values for parameter X from entire sonde inventory**
Standard Deviation = **± variation around the mean for [n] of X in a given month**

The monthly sonde charts display the monthly mean deltas plotted for each parameter versus time (calibration date). Each graph represents one parameter and contains one data point per month. The standard deviation is represented on the graph as y-error bars for each corresponding point. The monthly sorted sonde performance data are presented in appendix B.

The performance of a station is measured by comparing two instruments at a given station at the same time, then subtracting the QA/QC sonde (standard) readings from the in-place instrument readings to calculate the delta values for TDG, DO, and temperature. The QA/QC sonde is considered the standard because, of the two instruments being compared, it was the one most recently calibrated in the lab. The Honeywell barometers at each station are also evaluated by subtracting the Surveyor 4 readings from the station barometer readings. Once the delta values are calculated, they are averaged on a monthly basis to calculate a monthly mean delta for each parameter. The standard deviation is also calculated for each parameter on a monthly basis. The following equations summarize the above description.

Delta TDG = **[In-Place Sonde TDG] - [QA/QC Sonde TDG]**
Delta DO mg/L = **[In-Place DO mg/L] - [QA/QC DO mg/L]**
Delta Temperature = **[In-Place Temperature] - [QA/QC Temperature]**
Delta Bar = **[Station Honeywell Bar] - [Surveyor 4 Bar]**
Monthly Mean Delta for parameter X
= **[Sum of Deltas for X] / [n] where n = number of delta values for parameter X from entire system of stations**
Standard Deviation = **± variation around the mean for [n] of X in a given month**

The monthly station charts display the monthly mean delta values plotted for each parameter versus time (deployment date). Each graph represents one parameter and contains one data point per month. The standard deviation is represented on the graph as y-error bars for each corresponding point. The monthly sorted station performance data are presented in appendix C.

Sonde- and Station-Specific Charting and Calculations.

Each of the deployment stations and instruments is evaluated individually to determine which, if any, of these components may be malfunctioning. The TDG sensor *calibration* data and thermometer *performance* data for each instrument are plotted versus time (calibration date) in order to evaluate "Sonde-Specific Performance." Likewise, the station comparison data collected at individual stations are plotted to evaluate "Station-Specific Performance."

A performance chart represents each instrument with sufficient data. The chart contains thermometer *performance* data and TDG *calibration* data. The Base and Pressure *Net Cumulative TDG Calibration Adjustment* data are also represented on the graph, each as a line. The Net Cumulative Adjustment calculation reflects the cumulative adjustments made over time to the base and offset points of a TDG sensor calibration curve. Plotting this relationship provides insight about the bias of a sensor (tendency to drift over time in a particular direction in relation to the standard).

The *Delta* calculation is performed on the temperature data because HDR does not calibrate the thermometers (no adjustments are made). An *Adjustment* calculation is performed on the TDG calibration data. The *Adjustment* value represents the magnitude and direction that the base and offset points of a TDG calibration curve are adjusted to match their respective standards. The *Adjustment* value is calculated by subtracting the pre-calibrated TDG readings from the calibrated TDG readings. The Net Cumulative Adjustment value is calculated by adding each new Base or Pressurized TDG Adjustment value to the total of the values above them in their respective columns. The following equations and an illustration summarize the above descriptions.

Delta Temperature = [NBS Temperature] – [Sonde Temperature]
Base TDG Adjustment = [Calibrated Base TDG] – [Pre-Calibrated Base TDG]
Pres. TDG Adjustment = [Calibrated Pres. TDG] – [Pre-Calibrated Pres. TDG]
Net Cum Adjustment = (Net Cum Base calculation is shown below. Same calculation is made for Pressurized TDG Adjustments).

Calibration Date	Base TDG Adj.	Net Cum Base TDG Adj.
January 1	1	1
January 14	1	2
January 28	1	3

Each of the sonde charts displays the actual delta temperature and TDG adjustment values plotted versus time (calibration date). The Net Cum calculation is represented as a line on the graph. Instrument data sorted by sonde number are presented in appendix D.

Station-specific charts are based on the delta calculations performed on the data collected for each parameter at individual stations. Again, the QA/QC sonde is used as the standard to compare TDG, DO, and temperature with the in-place instrument, while the Surveyor 4 is used as a standard for barometric pressure to evaluate the station barometers. The following equations summarize the above description.

Delta TDG = [In-Place Sonde TDG] - [QA/QC Sonde TDG]
Delta DO mg/L = [In-Place DO mg/L] - [QA/QC DO mg/L]
Delta Temperature = [In-Place Temperature] - [QA/QC Temperature]
Delta Bar = [Station Honeywell Bar] - [Surveyor 4 Bar]

Each of the station charts displays the actual delta values for each parameter plotted versus time (deployment date). Station data sorted by station name are presented in appendix E.

Data Quality Objectives.

The QC officer sets DQO's for each parameter based either on environmental regulations or manufacturer precision levels. The following DQO's were established for instrument calibration: TDG > ±2 mm Hg and temperature > ±0.10° C. The following DQO's were selected for station comparison data: TDG > ±4 mm Hg and temperature > ±0.20° C. These levels are goals as much as they are thresholds. As improvements are made to the system, these levels may be lowered to encourage continued improvement.

System Audits.

When a decreasing data quality trend or bias is recognized, a system audit is initiated to determine the root cause. The system audit begins with a ground up evaluation of the entire TDGMS for any detectable error. This error can be in instrumentation, procedure, transmission, or calculation.

RESULTS

Site-Specific Data Quality.

Records show that all stations experienced occasional short-term outages. Some of these were instrument malfunctions and some were power or transmission errors. Outages that lasted for more than 2 hours are discussed below. In addition, a brief explanation about the outlying data points is offered for each chart that contains outlying data points.

The results of the statistical analyses performed on the QA/QC data for the entire system of stations indicate that the stations performed within the upper and lower QC limits and the DQO's for most of the time.

The DQO for TDG comparison delta values is 4 mm Hg. The results of the cumulative analyses indicate that the mean delta value for the TDG comparison was 0.09 mm Hg with a standard deviation of ±2.39. The DQO for temperature comparisons at the stations is 0.2° C. The results of the cumulative analyses indicate that the cumulative temperature variance calculated for all of the stations resulted in a mean delta value of 0.00° C with a standard deviation of ± 0.07° C. This is well within the manufacturer's specifications and the district's DQO's. These results indicate that the stations are performing their task well, which is to protect the instruments while exposing them to adequate volumes of fresh sample.

Monthly Station Data

Month	Avg Delta TDG*	Stdev TDG	Avg Delta Temp**	Stdev Temp
October	nd	nd	nd	nd
November	nd	nd	nd	nd
December	nd	nd	nd	nd
January	nd	nd	nd	nd
February	nd	nd	nd	nd
March	-0.20	2.24	-0.03	0.07
April	0.59	2.39	0.00	0.08
May	0.17	2.57	0.00	0.07
June	0.29	3.16	0.01	0.08
July	-0.53	1.94	-0.01	0.07
August	0.24	1.85	-0.03	0.07
September	0.00	2.03	0.00	0.04
Cumulative	0.09	2.39	0.00	0.07

nd = No Data (statistical analyses began in March 2000)

*** results are reported in mm Hg**

**** results are reported in ° C**

Table 2. Monthly and Cumulative Mean Delta and Standard Deviation Calculations for Entire Inventory of TDG and Temperature Sensors.

a. Station ANQW - Snake River at Anatone, Washington.

The Anatone station is on the left side of the river at river mile (RM) 167.5. The station operated continuously from 1 October 1999 until 30 September 2000 although the station was only calibrated from 1 April 2000 until 15 September 2000. Data is good for the period of calibration except for data between about 29 July 2000 and 2 August 2000. River silt accumulated around the end of the probe and reduced the circulation near the sensors. Consequently, dissolved gas readings were lower during this period. By early June, the silting had begun to prevent adequate fresh sample from reaching the instruments. This had a dramatic impact on data quality so, in mid-June the decision was made to deploy the instruments outside the protective deployment pipe on a full-time basis. This event occurred at the same time that the new barometer was being incorporated in the calibration procedures. The large delta TDG and temperature values can be attributed to both these events.

Data Points Failing QA/QC Standard

Period	Value	Values	Typ Range
0729 2100 - 0802 1300	TDG	<90	95 - 120

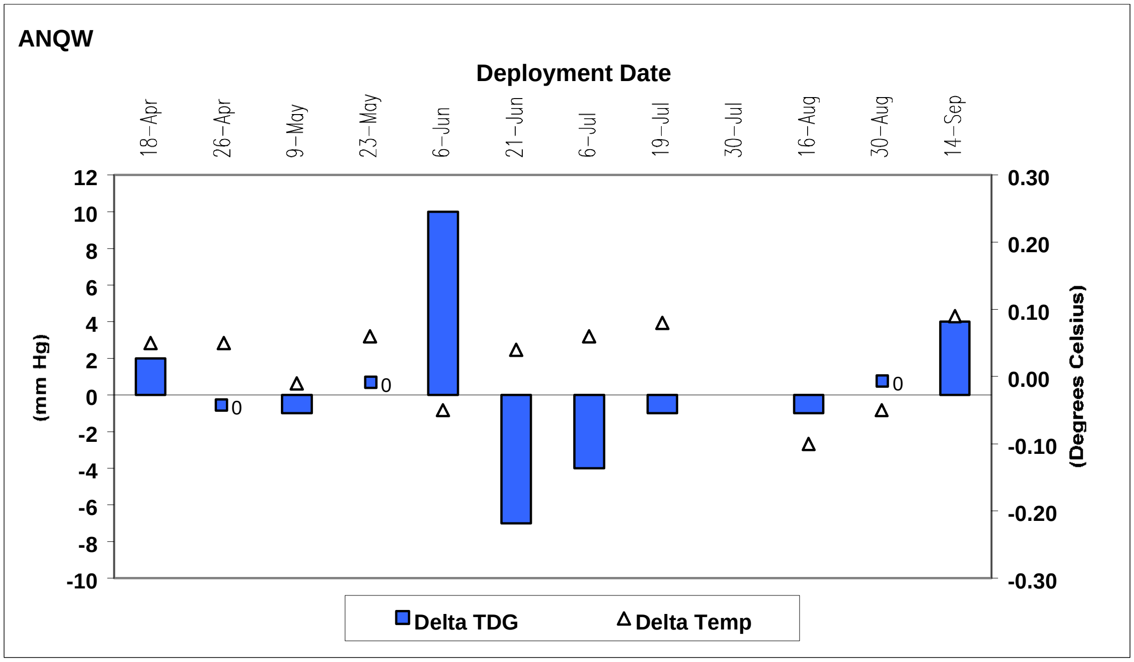


Figure 2. Control Chart for Station ANQW.

b. Station DWQI - North Fork of the Clearwater River Below Dworshak Dam, Idaho.

Dworshak Dam's tailwater station is on the left bank at RM 0.5. It is approximately 7,900 feet downstream of the dam. The station operated continuously from 1 October 1999 until 30 September 2000. Several short outages occurred. On 31 May 2000, the station was down while the modem was serviced. Readings show gaps and abnormally high readings for that period. From 23 June 2000 until 5 July 2000, the station went through a period of sporadic outages lasting 4 to 12 hours. Cables were systematically replaced until the station resumed operation. The readings that were transmitted seem to be in the normal range for this station.

The higher delta TDG values in June are related to the implementation of a new barometric pressure standard that is used to calibrate the instruments and does not reflect a decrease in the ability of the station to provide fresh sample to the instruments. Notice the increased precision for both TDG and temperature after the implementation of new standards and calibration procedures.

Data Points Failing QA/QC Standard

Period	Value	Values	Typ Range
0531 1000 - 0531 2000	TDG	>150	95 - 120
0531 1000 - 0531 2000	BP	>700	550 - 700
0531 1000 - 0531 2000	WT	>100	40 - 70
0623 1800 - 0705 1300	TDG	0	95 - 120
0623 1800 - 0705 1300	WT	0	40 - 70

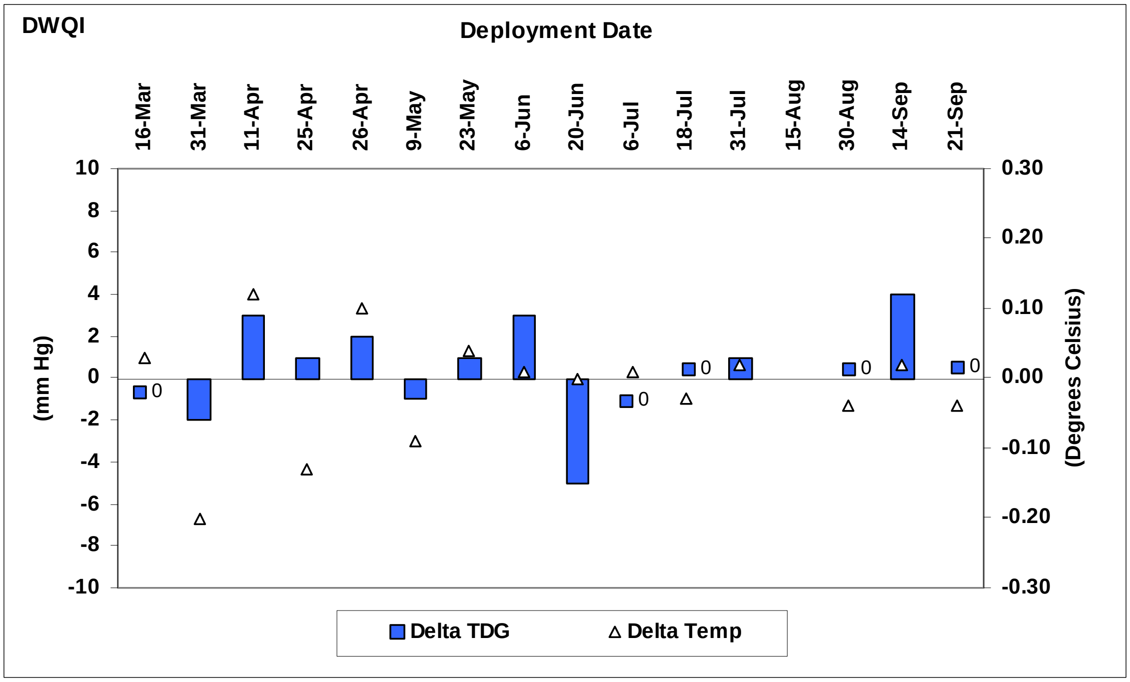


Figure 3. Control Chart for Station DWQI.

c. Station LEWI - Clearwater River at Lewiston, Idaho.

The Lewiston station is on the right side of the river near the city's water intake at RM 5.1. The station operated continuously from 1 April 2000 until 30 August 2000. The station would normally be active until 15 September 2000 but low flows made monitoring impossible. In addition, the station experienced several short outages of 1 to 3 hours.

Data Points Failing QA/QC Standard

Period	Value	Values	Typ Range
0606 1500 - 0606 1600	TDG	No Data	95 - 120
0624 2200 - 0624 2400	TDG	>125	95 - 120
0624 2200 - 0624 2400	WT	0	40 - 70
0624 2200 - 0624 2400	BP	0	750 - 800
0625 2300 - 0625 2400	WT	0	40 - 70
0625 2300 - 0625 2400	BP	0	750 - 800

d. Station PEKI - Clearwater River at Peck, Idaho.

The Peck station is on the left side of the Clearwater River at RM 37.4. The station operated continuously from 1 April 2000 until 2 September 2000. Like the station at Lewiston, Peck would have been active until 15 September but low flows prevented access to the water.

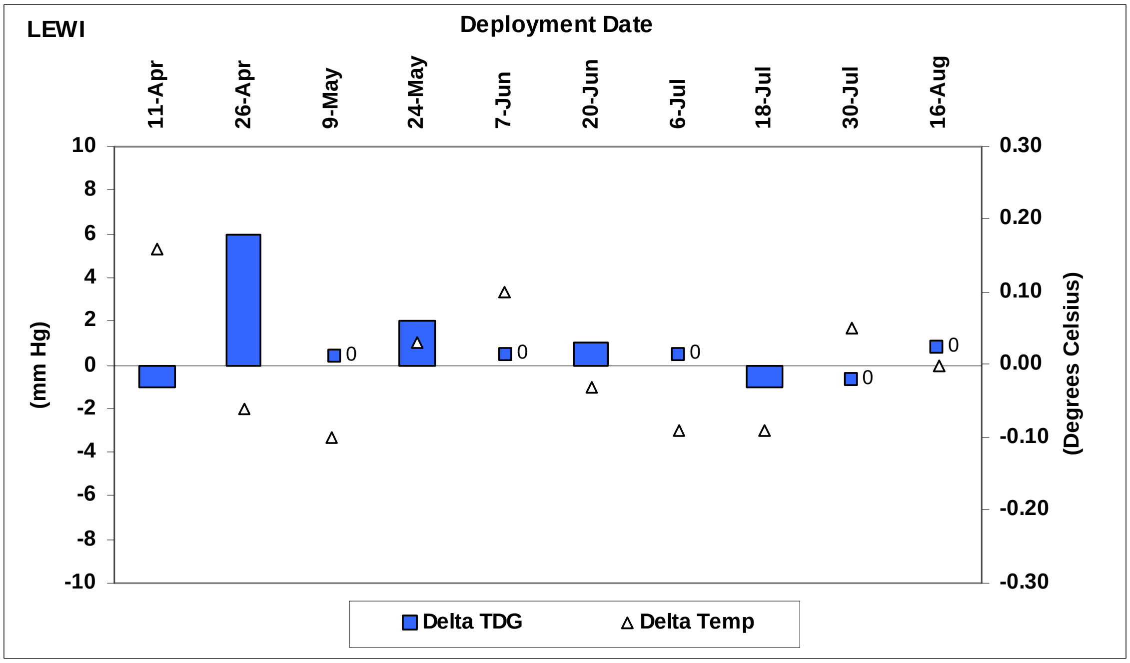


Figure 4. Control Chart for Station LEWI.

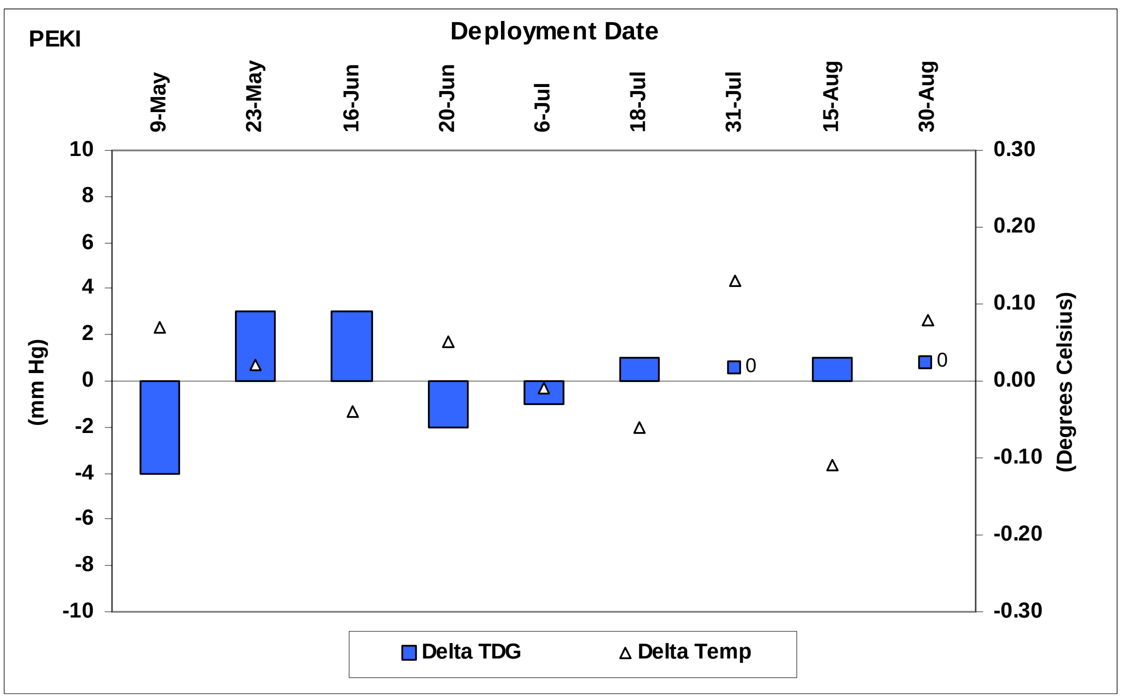


Figure 5. Control Chart for Station PEKI.

e. Station LWG - Snake River at Forebay at Lower Granite Dam, Washington.

This station is located at the end of the navigation lock guide wall, about 630 feet upstream of the dam and right of the middle of the river. The station operated continuously from 1 October 1999 until 30 September 2000 with no outages.

The data quality at this station reflects changes that were made to the standard operating procedures in May 2000 and the incorporation of the new standards in June to July 2000. After each of these changes, the station performance returned to normal. The larger delta TDG in late August marks the beginning of an increasing trend that continued on into the next fiscal year. This increase in delta TDG is likely related to poor circulation in the forebay pool as described in previous sections.

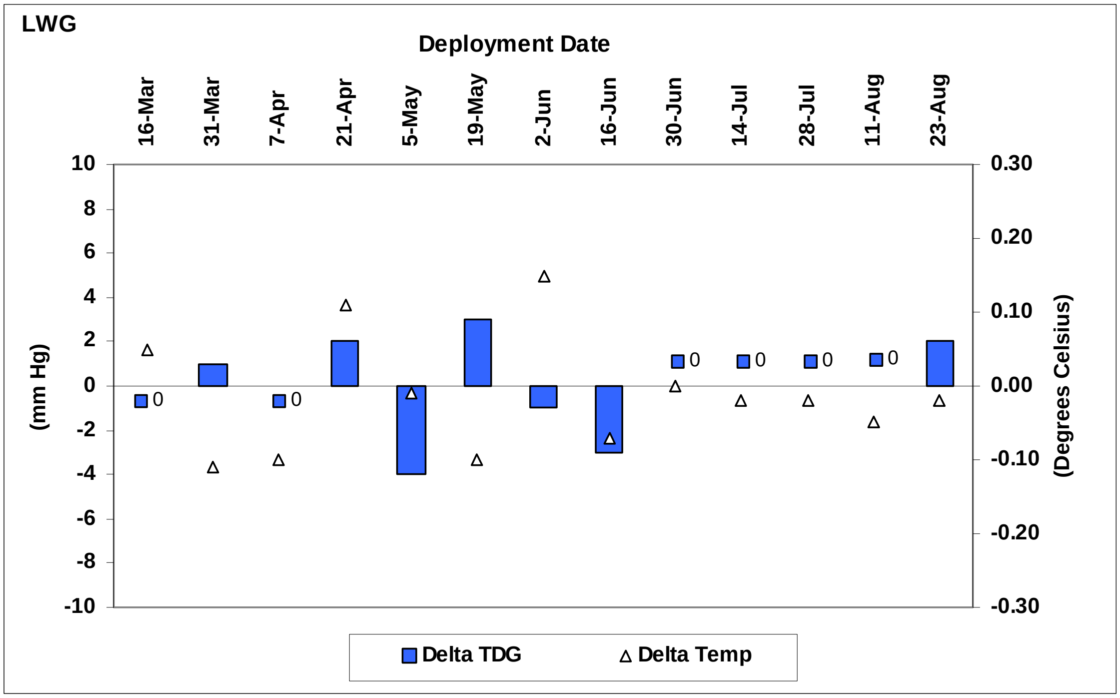


Figure 6. Control Chart for Station LWG.

f. Station LGNW - Snake River Below Lower Granite Dam, Washington.

Lower Granite's tailwater station is on the right bank at RM 106.8, approximately 3,500 feet downstream of the dam. The station operated continuously from 1 October 1999 until 30 September 2000 with no unexpected outages.

This station provided high quality data throughout the entire year. The delta values in June 2000 can be attributed to the new standards used for instrument calibration. They do not reflect station performance.

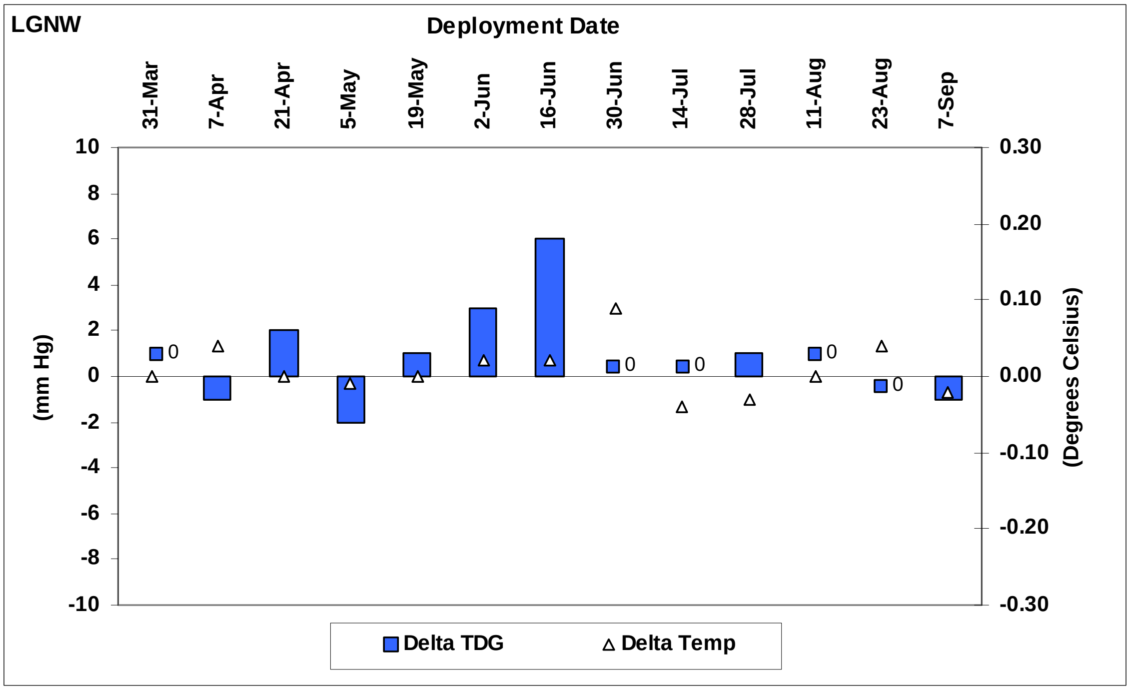


Figure 7. Control Chart for Station LGNW.

g. Station LGS - Snake River at Forebay at Little Goose Dam, Washington.

This station is on the face of the dam at about mid-river. The station operated continuously from 1 April 2000 until 15 September 2000 with no extended outages.

This station provided high quality data throughout the entire year. The delta values in June 2000 can be attributed to the new standards used for instrument calibration. They do not reflect station performance.

h. Station LGSW - Snake River Below Little Goose Dam, Washington.

This tailwater station is on the right bank at RM 69.5, about 3,900 feet downstream of the dam. The station operated continuously from 1 April 2000 until 15 September 2000 with two short outages. Three hours of data were lost on 26 June 2000 due to unknown causes and faulty servicing on 7 September 2000 caused a break in data that lasted until the next day. Again, slow posting of data caused the problem to go unnoticed during the afternoon of 7 September 2000.

Data Points Failing QA/QC Standard

Period	Value	Values	Typ Range
0626 0600 - 0626 0900	TDGP	<500	750 - 800
0626 0600 - 0626 0900	WT	No Data	40 - 70
0907 1600 - 0908 1200	TDG	0	95 - 120
0907 1600 - 0908 1200	WT	0	40 - 70

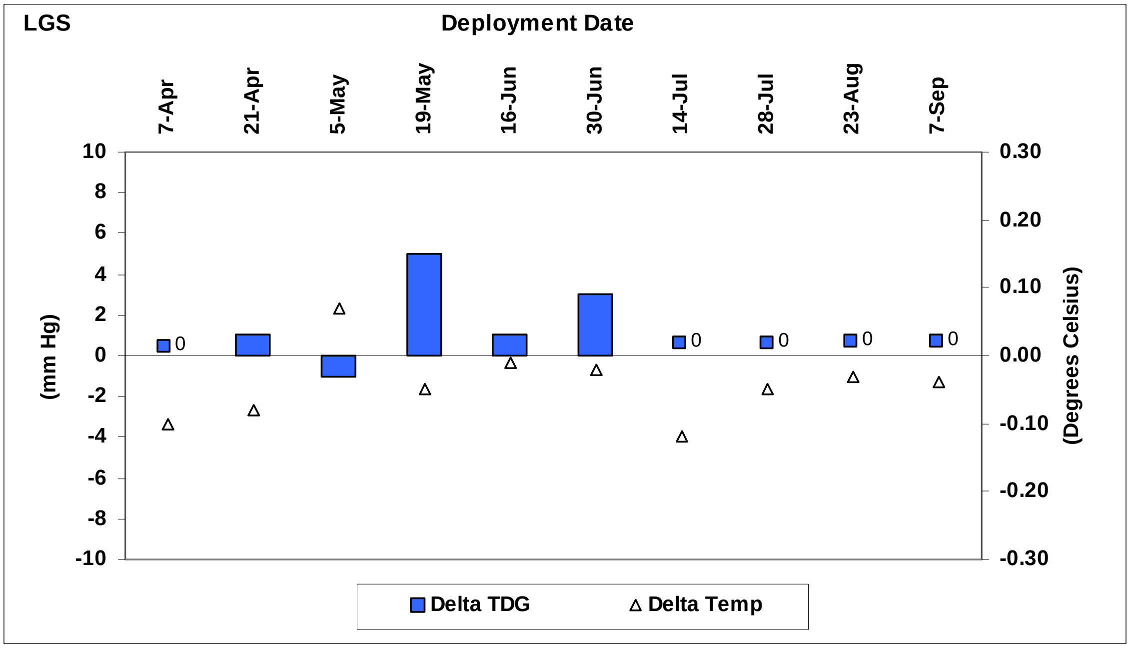


Figure 8. Control Chart for Station LGS.

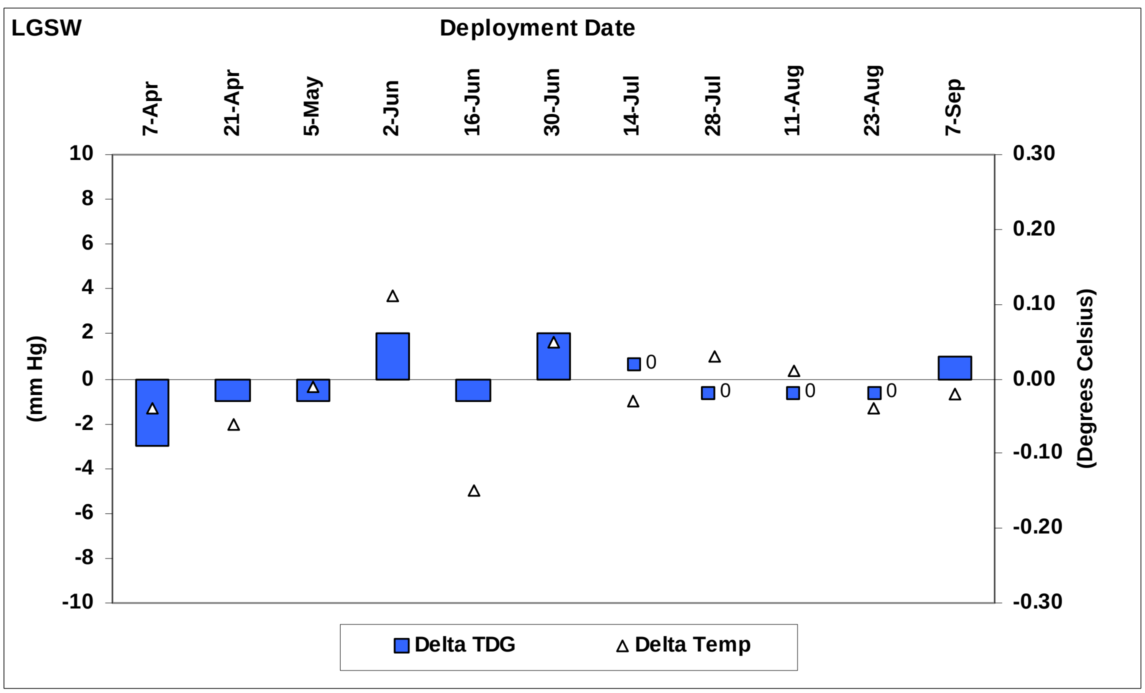


Figure 9. Control Chart for Station LGSW.

i. Station LMN - Snake River at Forebay at Lower Monumental Dam, Washington.

This station is on the face of the dam at about mid-river. The station operated continuously from 1 April 2000 until 15 September 2000 with no extended outages.

The positive impact that the new calibration standards had on station performance is very evident at this station. In late June, after the new barometer and thermometer were incorporated into procedures, the TDG and temperature data improved dramatically.

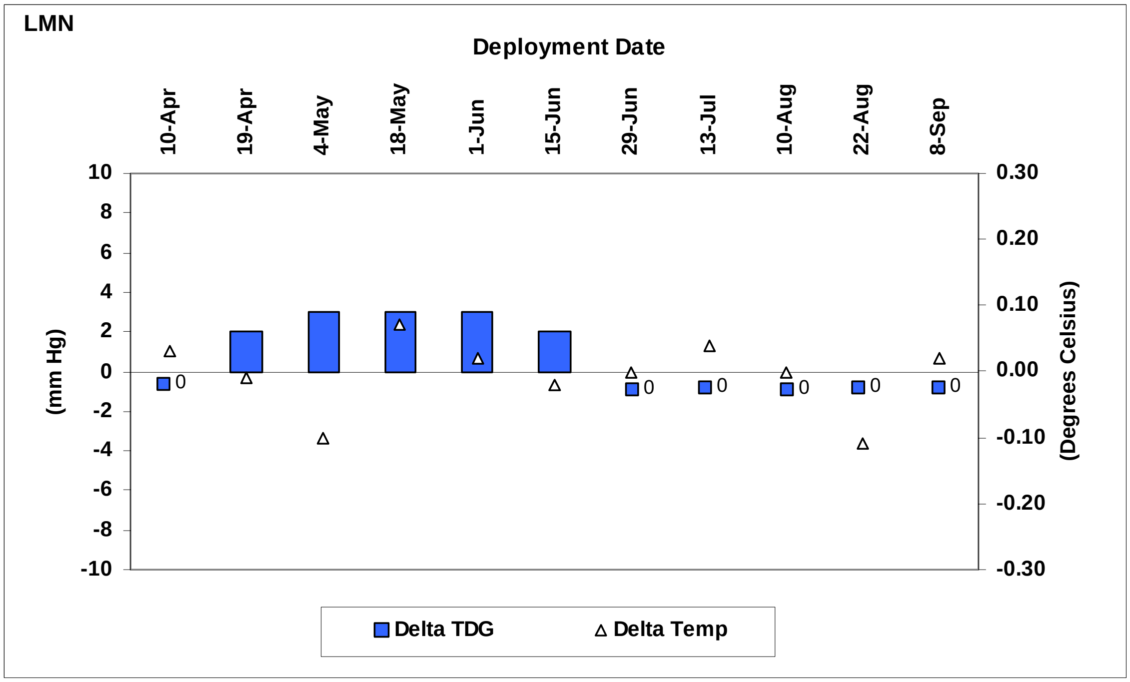


Figure 10. Control Chart for Station LMN.

j. Station LMNW - Snake River Below Lower Monumental Dam, Washington.

This station is on the left bank at RM 40.8, approximately 4,320 feet downstream of Lower Monumental dam. The station operated continuously from 1 April 2000 until 15 September 2000 with a short outage on 18 May 2000 from 1300 until 19 May 2000 at 1300. Routine service resulted in a bad electrical connection. Slow posting of data prevented the problem from being discovered until the next day. The station went partially down again on 25 August 2000 at 1800 but self-started again at 0400 on 27 August 2000. No service was required. The cause of failure was never determined.

Data Points Failing QA/QC Standard

Period	Value	Values	Typ Range
0518 1300 - 0519 1200	TDG	0	95 - 120
0518 1300 - 0519 1200	WT	32 (° C)	40 - 70
0825 1800 - 0827 0300	TDG	0	95 - 120

The data quality at this station reflects changes that were made to the standard operating procedures in May 2000 and the incorporation of the new standards in June to July 2000. After each of these changes, the station performance returned to normal.

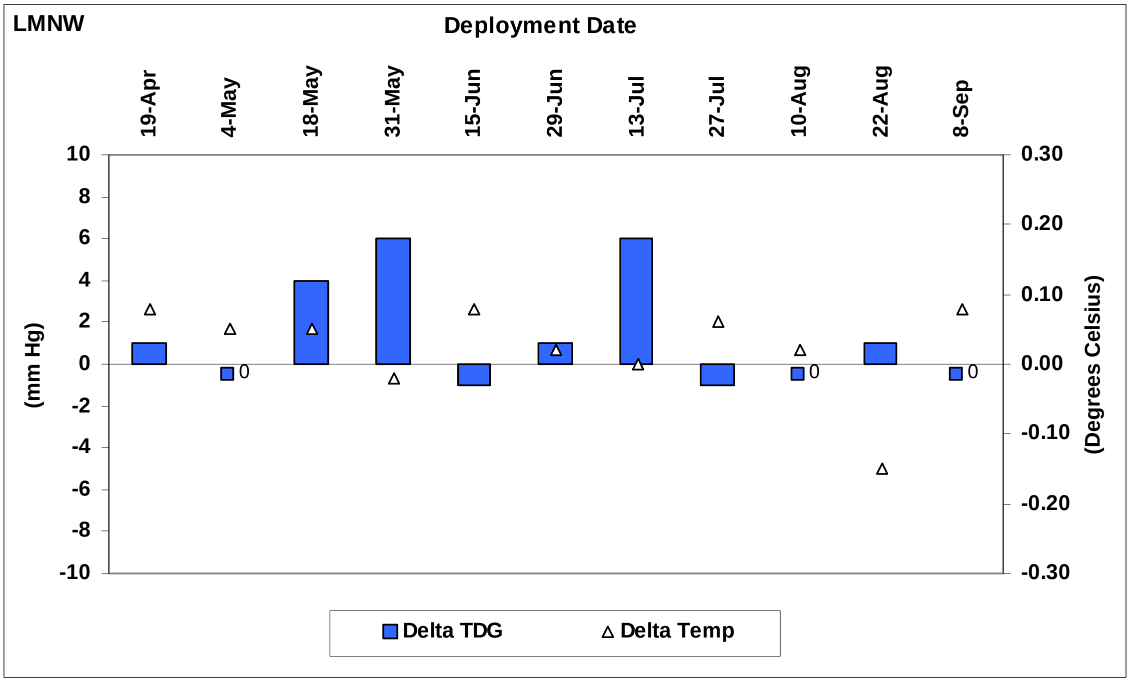


Figure 11. Control Chart for Station LMNW.

k. Station IHR - Snake River at Forebay at Ice Harbor Dam, Washington.

The Ice Harbor station is mounted on the upstream face of the dam approximately at mid-river. The station operated continuously from 1 October 1999 until 30 September 2000 with no extended outages.

The station performed very well throughout the spring and summer. As the fish passage season came to an end in early September, the reduction in spill levels caused the circulation in the pool to diminish and likely caused stagnation in and around the deployment pipe that resulted in larger delta values. The small circulators on the instruments could not adequately mix the stagnant water, causing each instrument to read the water quality in its own microenvironment. This scenario is common among the forebay stations and is consistent with data from other years. There are improvements planned to address this issue. One solution may be to install small circulating pumps inside the pipe to purge the pipe several times an hour to ensure that an adequate volume of fresh sample can reach the instruments.

l. Station IDSW - Snake River Below Ice Harbor Dam, Washington.

The Ice Harbor tailwater station is on the right bank at RM 6.8 and is 15,400 feet downstream of the dam. The station operated continuously from 1 October 1999 until 30 September 2000 but had a problem on 12 July 2000. The electrical cable was vandalized and the station stopped reporting at 0700 12 July 2000. A technician serviced the unit at 1100 on 13 July 2000. The station completed one 4-hour cycle and failed again due to a fault in the replacement cable. A second servicing brought the station back on-line on 14 July 2000.

Data Points Failing QA/QC Standard

Period	Value	Values	Typ Range
0712 1700 - 0714 1200	TDG	0	95 - 120
0712 1700 - 0714 1200	WT	32 (° C)	40 – 70

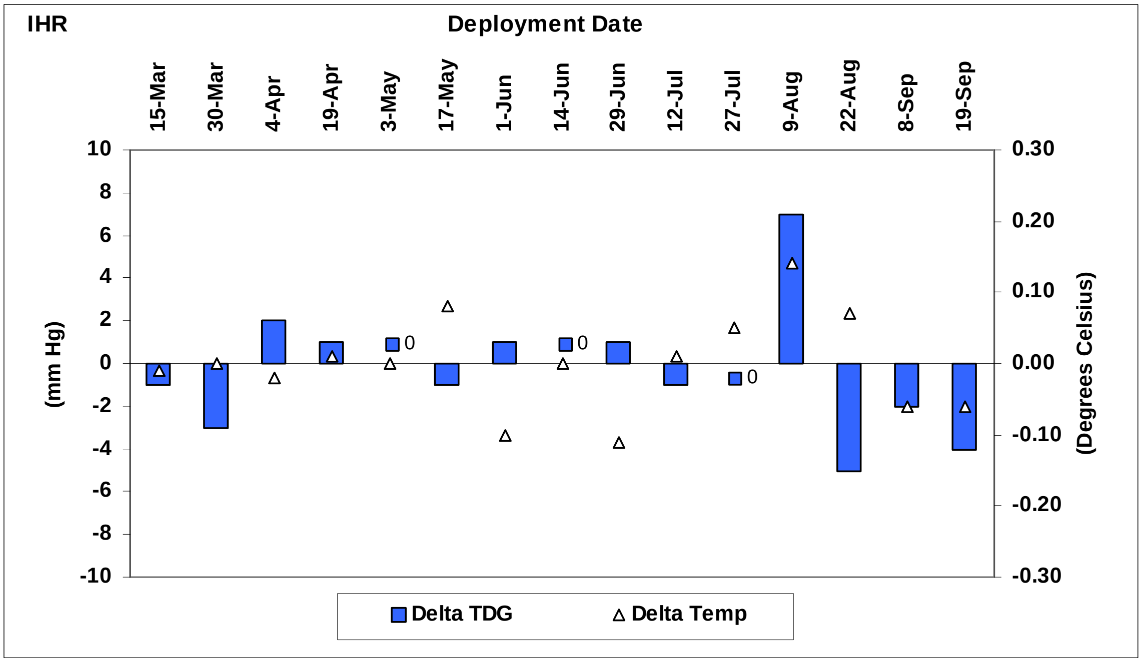


Figure 12. Control Chart for Station IHR.

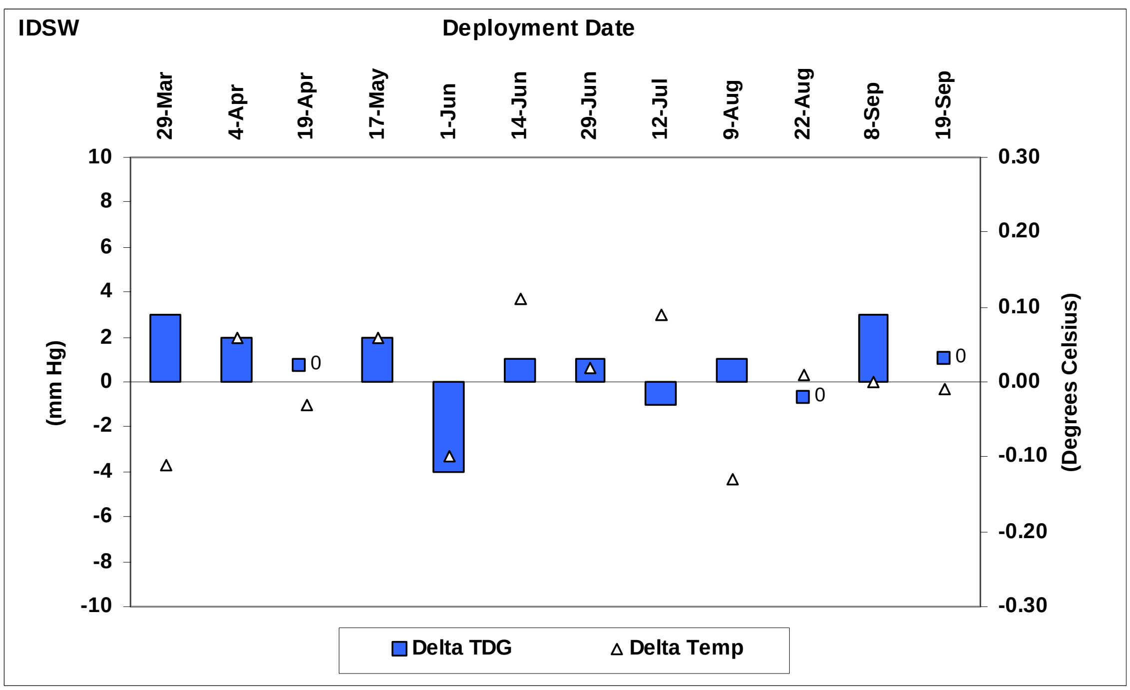


Figure 13. Control Chart for Station IDSW.

m. Station PAQW - Columbia River at Pasco, Washington.

The Pasco station is on the left side of the river at RM 392.0. The station operated continuously from 1 April 2000 until 15 September 2000. An outage occurred on 22 August 2000 at 0700 following routine station service. Due to slow reporting, the problem wasn't discovered until 23 August 2000 and was quickly fixed. The station was non-reporting from 0700 22 August 2000 until 1100 23 August 2000. The cause is unknown.

Data Points Failing QA/QC Standard

Period	Value	Values	Typ Range
0822 0700 - 0823 1100	TDG	<50	95 – 120

The only two delta TDG values worth noting are both related to instrument performance and not station performance. The 4 April 2000 value is related to modifications in the standard operating procedures for calibrating the instruments. The 28 June 2000 value is related to the incorporation of the new barometer standard into the system.

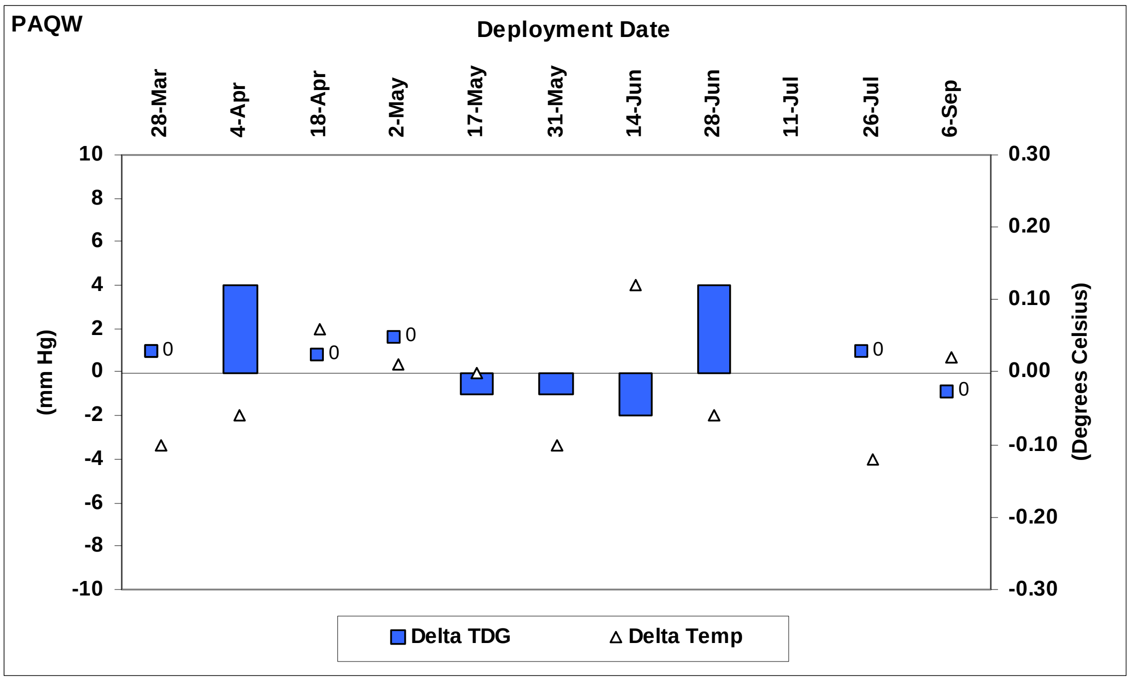


Figure 14. Control Chart for Station PAQW.

n. Station MCQO - Columbia River Forebay at McNary Dam, Oregon.

The McNary forebay station on the Oregon side is located on the upstream face of the dam. The station operated continuously from 1 October 1999 until 30 September 2000 with no outages.

New standard operating procedures in May, new standards in June-July, and late-season forebay circulation dynamics all overlap to account for the sporadic delta values at this station. The underlying station performance is quite good and the station performance data for the following year should improve based on the changes made this season.

o. Station MCQW - Columbia River Forebay at McNary Dam, Washington.

The McNary forebay station on the Washington side is mounted on the upstream end of the Washington shore fish ladder, about 295 feet upstream of the dam. The station operated continuously from 1 October 1999 until 30 September 2000 with no problems.

Station MCQW experienced the same improvements that occurred at MCQO; however, this station did not produce such large delta values late in the fish passage season. This is likely due to the fact that this station is located on the Washington side of the river and is mostly influenced by the Columbia River discharge, which is much greater than the Snake River discharge that influences the Oregon side of the pool. This station is also located approximately 100 feet from the dam, removing it from the stagnant water trapped between the closed spillway structures.

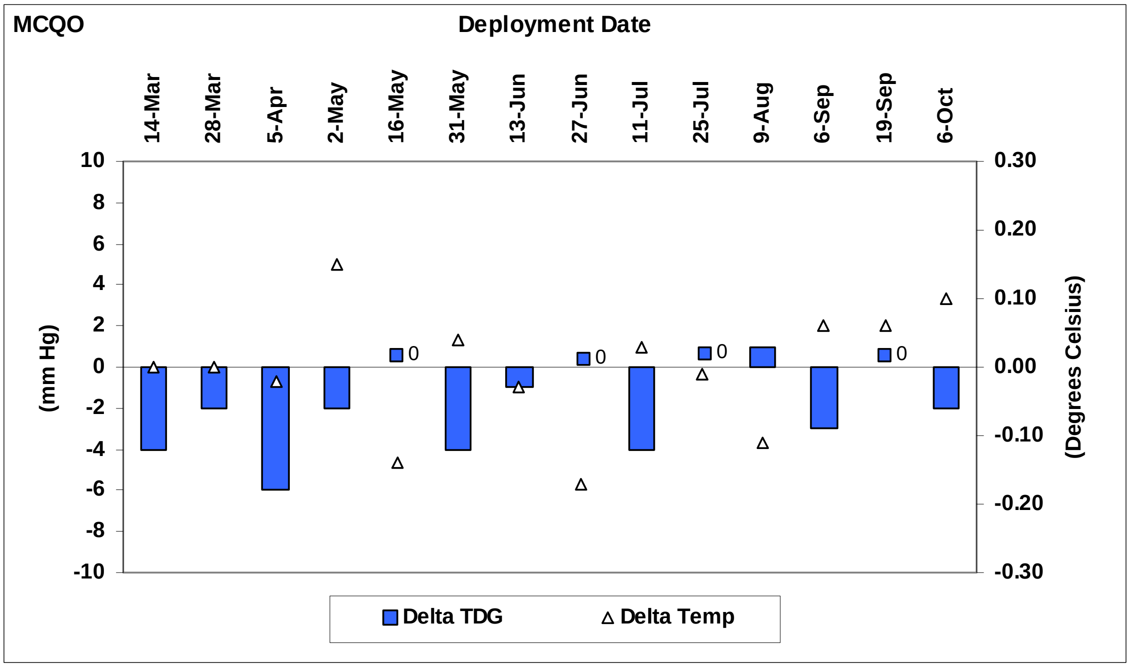


Figure 15. Control Chart for Station MCQO.

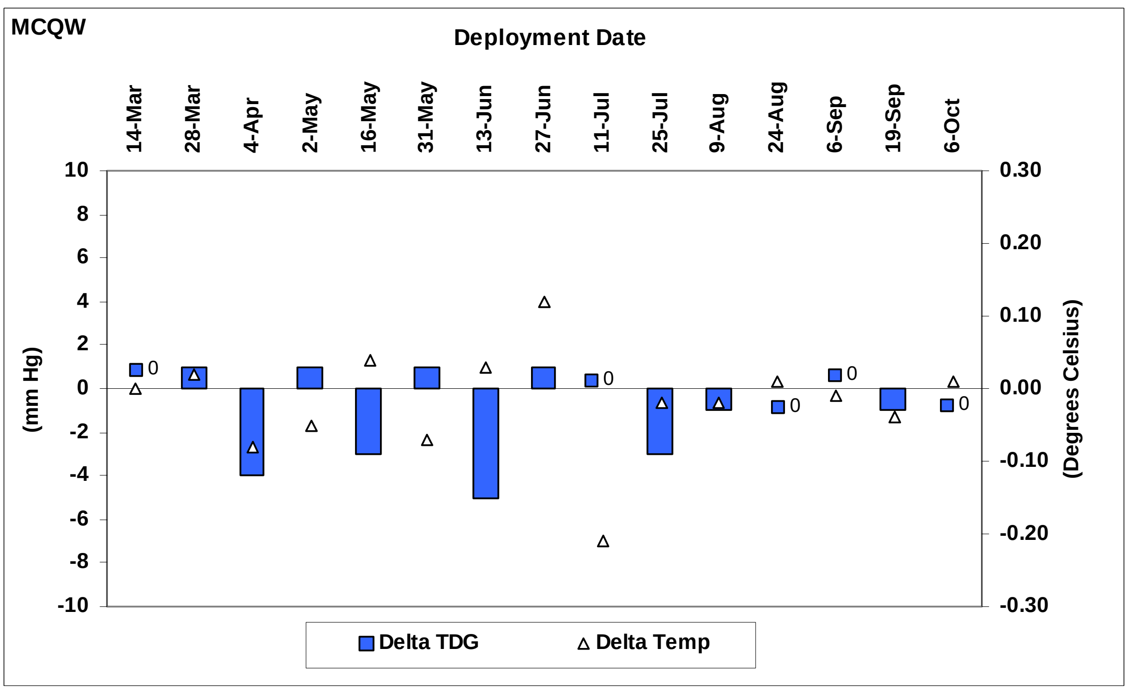


Figure 16. Control Chart for Station MCQW.

p. Station MCPW - Columbia River Below McNary Dam, Washington.

The McNary tailwater station is located on the right bank at RM 290.6, which is approximately 7,300 feet downstream of the dam. The station operated continuously from 1 October 1999 until 31 September 2000 with two short outages. One was at 0900 on 27 April 2000. Water temperature and dissolved gas sensors recorded high readings for 3 hours followed by 18 hours of low water temperature readings. The second outage was at 1000 on 16 June 2000 following battery replacement. The succeeding four reports failed to transmit.

Data Points Failing QA/QC Standard

Period	Value	Values	Typ Range
0427 0900 - 0427 1200	TDG	>120	95 - 120
0427 0900 - 0428 0400	WT	V>50, V<40	40 - 70
0616 1000 - 0616 1300	TDG	No data	95 - 120
0616 1000 - 0616 1300	WT	No data	40 - 70

Incorporation of the new barometer into the standard operating procedures improved the station performance data by increasing the precision of the instruments.

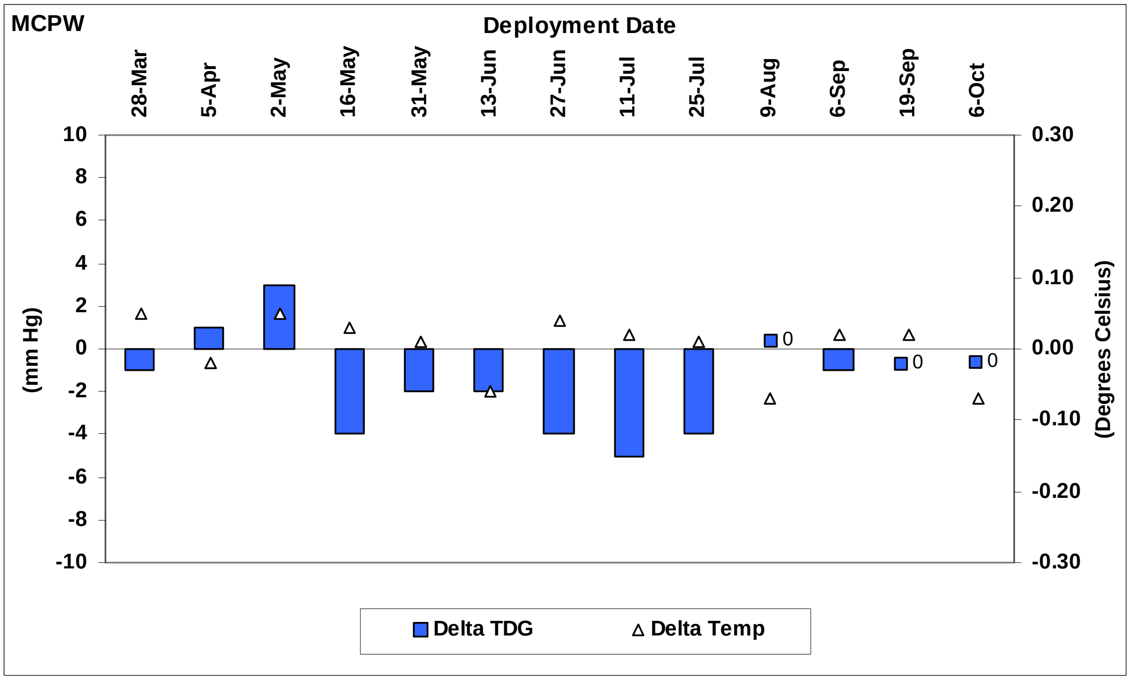


Figure 17. Control Chart for Station MCPW.

Individual Water Quality Sonde Performance.

The individual sondes are, in many ways, the major components of the system and require the highest level of maintenance and QA. Based on historic data, CENWW decided that performing calibration procedures in a laboratory produced the most precise and reproducible results. It is difficult to attempt calibration in the field under dynamic and sometimes adverse conditions. Furthermore, the mercury NBS standards and highly sensitive pressure calibrator devices are dangerous and costly to transport in the field. Subsequent paragraphs describe the individual sonde performance and history. This information was used to make in-season determinations of sonde mission capability and fleet management.

The results of the statistical analyses performed on the QA/QC data for the entire inventory of instruments indicate that the instruments performed within the upper and lower QC limits and the DQO's for most of the time. Data recorded by faulty or failing sensors were not used in the overall performance evaluation.

The DQO for TDG calibration delta values is 2 mm Hg. The results of the cumulative analyses indicate that the mean delta value for the Base TDG calibration parameter was 0.13 mm Hg with a standard deviation of ±1.07. The mean delta value for the Pressurized TDG calibration parameter was 0.25 with a standard deviation of ±1.11. Both parameters are well below the DQO's for the year.

The DQO for temperature is 0.10° C. The results of the cumulative analyses indicate that the cumulative temperature variance calculated for all of the instruments resulted in a mean delta value of -0.04° C with a standard deviation of ±0.07° C. This is well within the manufacturer's specifications and the district's DQO's. The thermisters consistently read below the standard temperature by approximately 0.05° C. These sensors are factory calibrated and, therefore, this is likely an artifact of production. The precision of the thermisters is well within the manufacturer's specifications.

Month	Mean Delta Base TDG*	Stdev Base TDG	Mean Delta Pres TDG*	Stdev Pres TDG	Mean Delta Temp**	Stdev Temp
October	nd	nd	Nd	nd	nd	Nd
November	nd	nd	Nd	nd	nd	Nd
December	nd	nd	Nd	nd	nd	Nd
January	nd	nd	Nd	nd	nd	Nd
February	nd	nd	Nd	nd	nd	Nd
March	-0.19	1.05	0.31	0.87	nd	Nd
April	0.36	0.95	0.71	1.08	-0.10	0.06
May	0.29	1.45	0.45	1.64	-0.04	0.06
June	0.26	1.07	0.14	1.12	-0.05	0.06
July	-0.09	1.09	0.03	0.89	-0.02	0.06
August	0.08	0.84	0.19	0.69	-0.04	0.09
September	-0.05	0.23	-0.16	0.37	-0.04	0.08
Cumulative	0.13	1.07	0.25	1.11	-0.04	0.07
nd = No Data (statistical analyses began in March 2000)						
*** - results are reported in (mm Hg)**						
**** results are reported in (Degrees Celsius)**						

Table 3. Monthly and Cumulative Mean Delta and Standard Deviation Calculations for Entire Inventory of TDG and Temperature Sensors.

a. Sonde #01.

This unit was deployed and actively used from the beginning to the end of last year's field season. It posed no real problems in calibration and was within 2 mm Hg of the NBS pressure standard or the QA/QC sonde throughout this season. The temperature was consistently 0.1° C lower than the calibrated QC or NBS standard. This was still within the manufacturer's warranty and specifications. This also met CENWW's control limits.

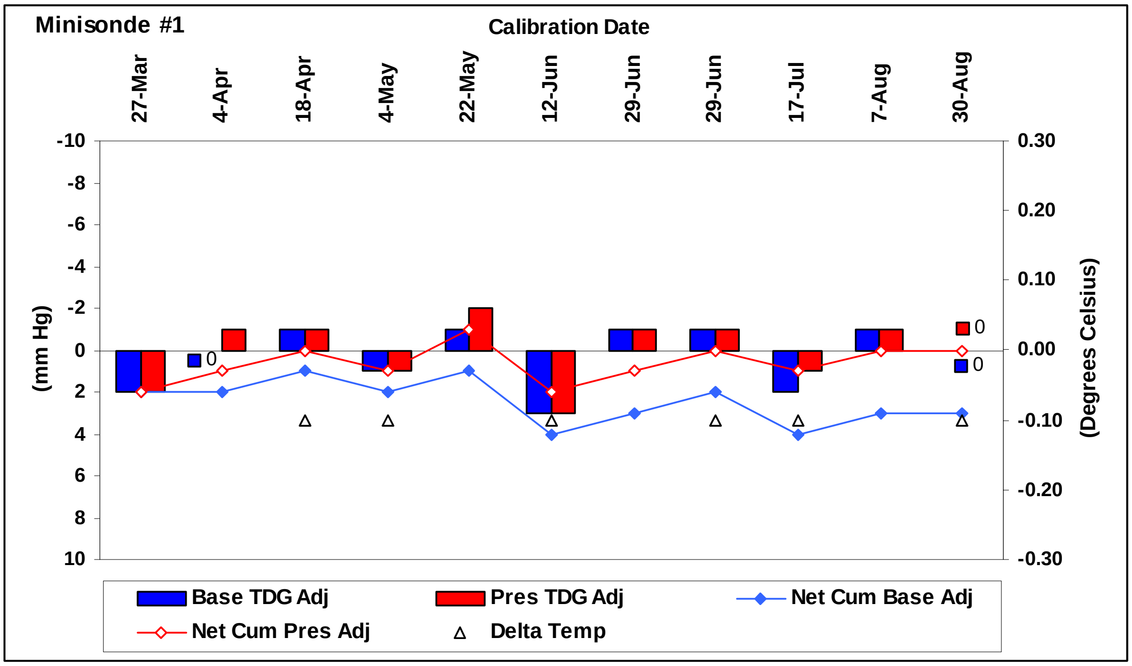


Figure18. Control Chart for Hydrolab Minisonde Serial Number 32431 (#01).

b. Sonde #02.

This unit was into the manufacturer for repairs and was not placed into general service until May. It posed no real problems in calibration and was within 2 mm Hg of the NBS pressure standard or the QA/QC sonde throughout this season. The temperature was consistently 0.1° C lower than the calibrated QC or NBS standard. This was still within the manufacturer's warranty and specifications. This also met CENWW's control limits.

c. Sonde #03.

This unit was in service for most of the season. In late June and early July, there were some pressure calibration problems. After a factory calibration and service of the pressure transducer, it gave near perfect performance in August. It was on the average within 2 mm Hg of the NBS pressure standard or the QA/QC sonde throughout this season. The temperature was consistently 0.1 C° lower than the calibrated QC or NBS standard. This was still within the manufacturer's warranty and specifications. This also met CENWW's control limits.

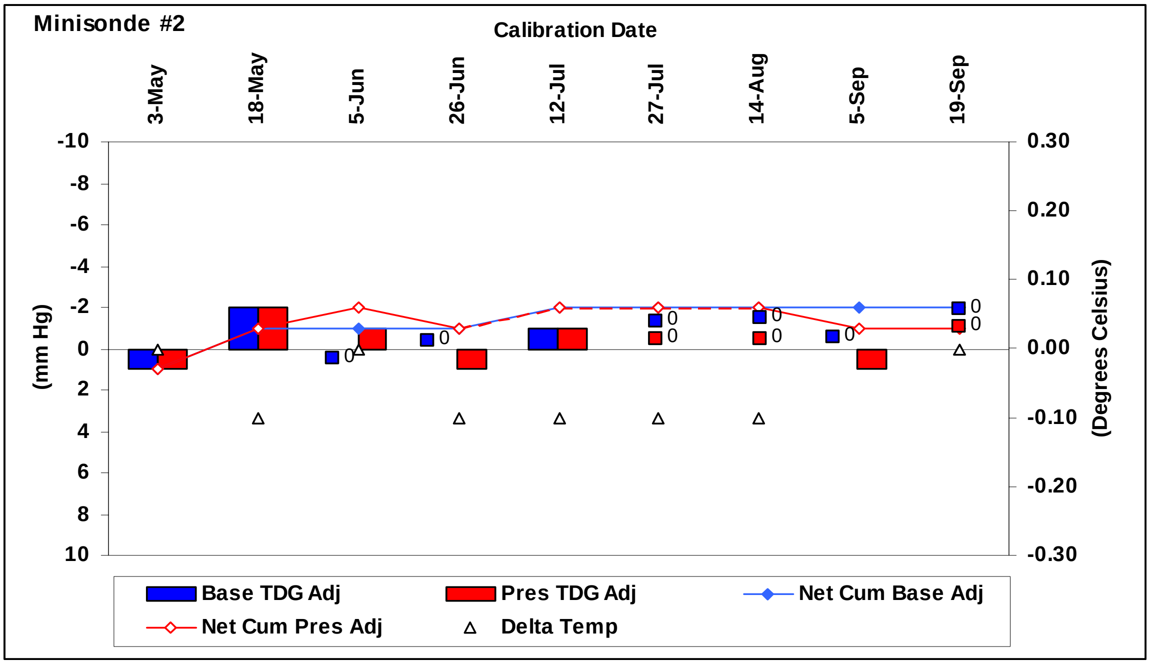


Figure 19. Control Chart for Hydrolab Minisonde Serial Number 32466 (#02).

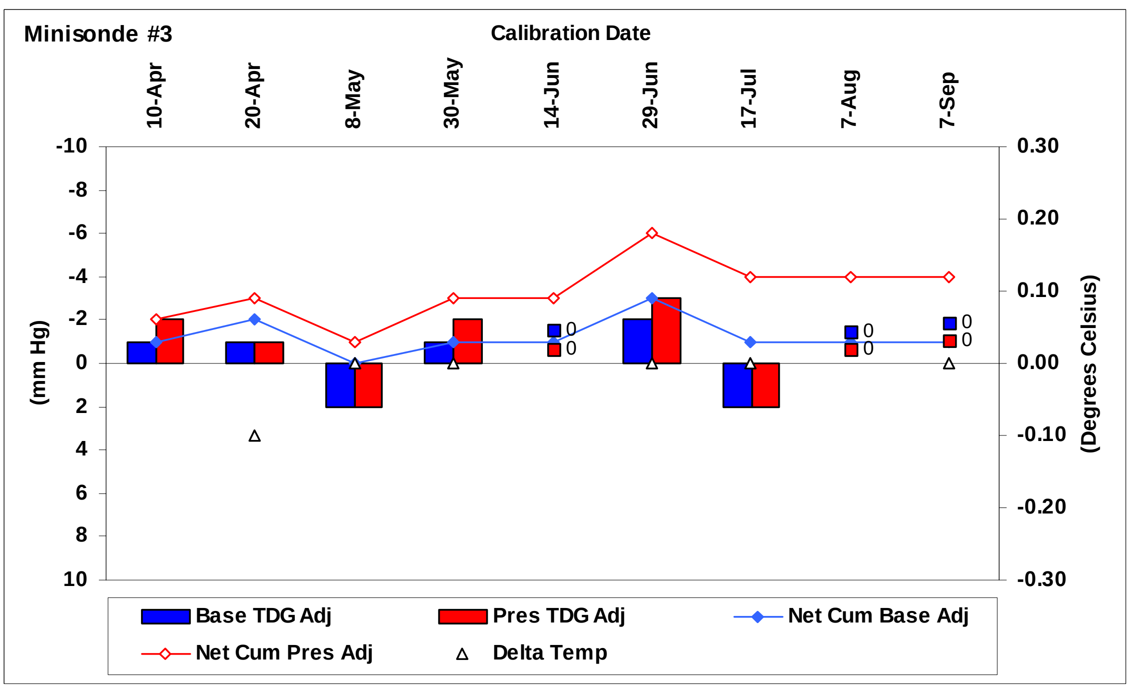


Figure 20. Control Chart for Hydrolab Minisonde Serial Number 32441 (#03).

d. Sonde #04.

This unit is operational but was retained at the CENWW lab for tests and evaluations or as an emergency backup in case a repair was needed on weekends. This unit was used as a static test unit in the hyperbaric chamber experiments. No comparable QA/QC station performance data was collected for this unit in water year 2000.

e. **Sonde #05.**

Unit #05 was utilized regularly during the season and provided excellent results. The unit did prove a little cantankerous to calibrate (it is part of the first batch of units procured) but once calibrated it exceeded manufacturer's specifications and our QA expectations. The temperature was almost always exactly the same as the NBS standard and the TDG averaged approximately within 1 mm Hg of accuracy. For all practical purposes this met all significant numbers and further QC would be a magnitude of order greater requiring new equipment and increased QA/QC. This unit is considered to be one of the best since further precision and accuracy beyond what this unit produces is not possible. This unit exceeds manufacturer's specifications and current QA/QC standards.

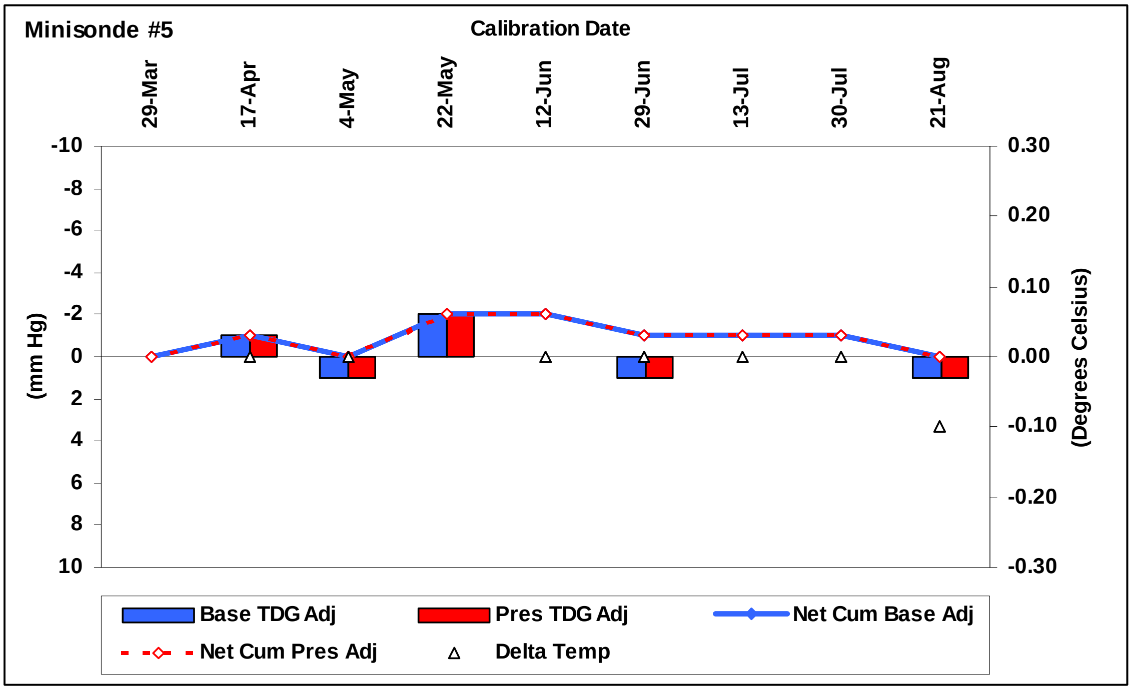


Figure 21. Control Chart for Hydrolab Minisonde Serial Number 32444 (#05).

f. **Sonde #06.**

This unit was used in April and May. In May, this unit became non-mission capable and remained in this state for the remainder of the year because, although it would calibrate, the data was not considered to be reliable when tested over a week's period in the lab. The QA officer decided to restrict its deployment until it received a complete overhaul at the factory. This unit is currently in a non-mission-capable status.

g. **Sonde #07.**

This unit started service in early March and was providing quality service until May. After two deployments, it was determined this unit was not meeting QC. The unit calibrated correctly but did not provide quality field service. The instrument had its software and drivers erased and updated with the latest Hydrolab firmware. From then on, it became one of the best performing units and maintained accuracy for months on end.

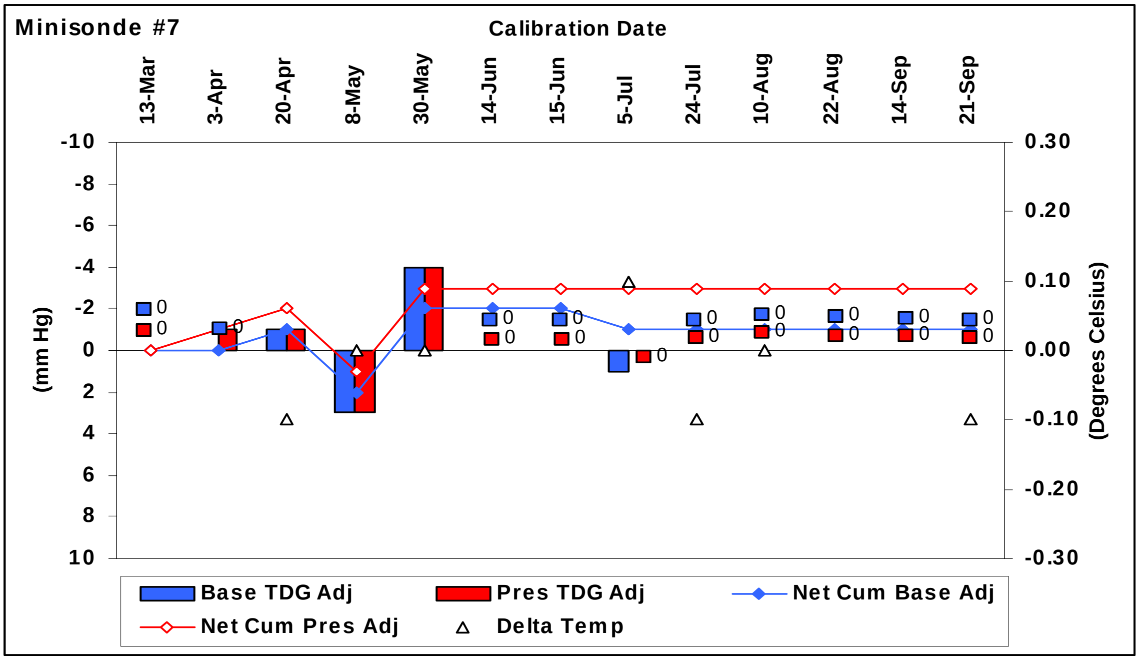


Figure 22. Control Chart for Hydrolab Minisonde Serial Number 32427 (#07).

h. Sonde #08.

This unit was deployed continuously during the field season and was utilized frequently as a QA/QC sonde. With the exception of two data points, this unit matched the standards. For all practical purposes this met all significant numbers and further QC would be a magnitude of order greater requiring new equipment and increased QA/QC. This unit is considered to be one of the best since further precision and accuracy beyond what this unit produces is not possible. This unit exceeds manufacturer's specifications and current QA/QC standards.

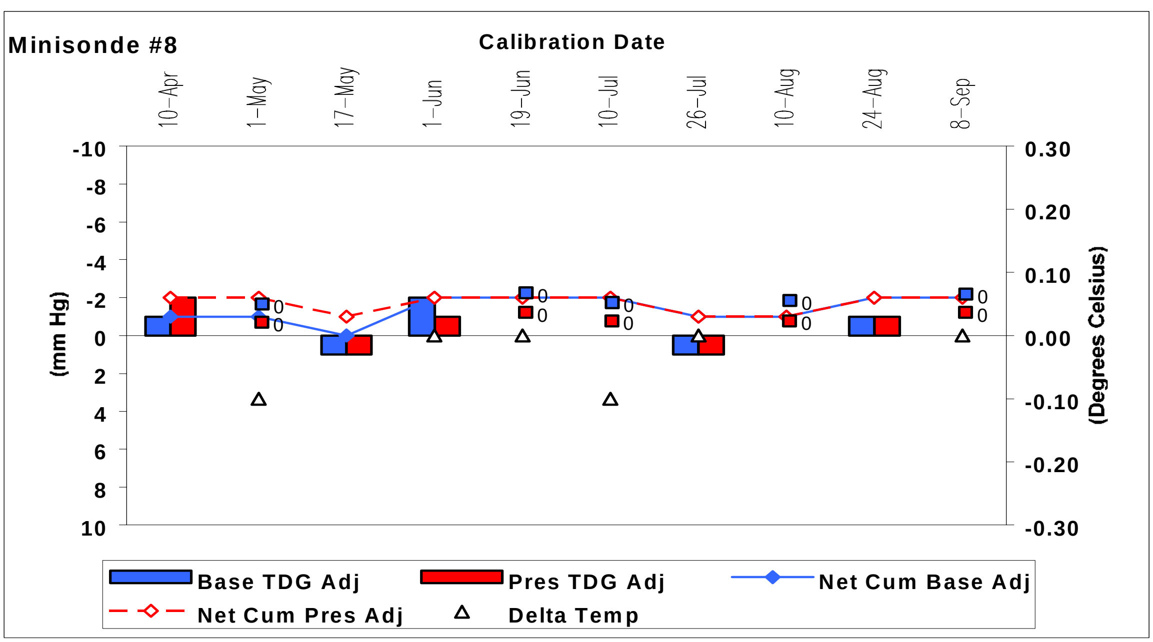


Figure 23. Control Chart for Hydrolab Minisonde Serial Number 32432 (# 08).

i. **Sonde #09.**

This unit was utilized for the first 2 months of this season. In May, the instrument received physical damage and was not repaired until August. The unit was utilized in early water year 2001 with success.

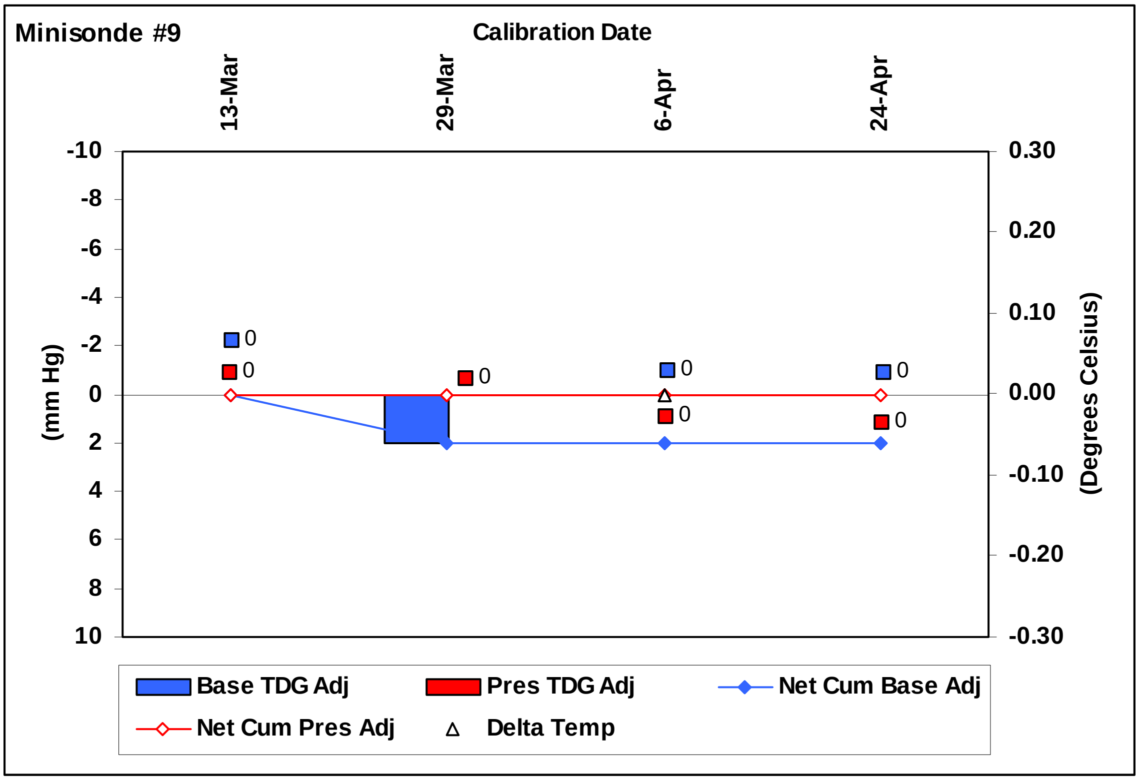


Figure 24. Control Chart for Hydrolab Minisonde Serial Number 32420 (#09).

j. **Sonde #10.**

This unit was in service a majority of the time during this year's season. The temperature was nearly identical to the NBS standard. The TDG sensor did fluctuate throughout the period of service but was within the QA/QC and the manufacturer's specifications. In July and August, the instrument tolerances were at the loosest. However, after thorough lab tests and evaluation no problems were detected and it performed perfectly in September.

k. **Sonde #11.**

This instrument was used for most of the season. There was a bit more flux in the temperature sensor as compared to some of the better instruments. This instrument did perform within the manufacturer's specifications and met CENWW's QC.

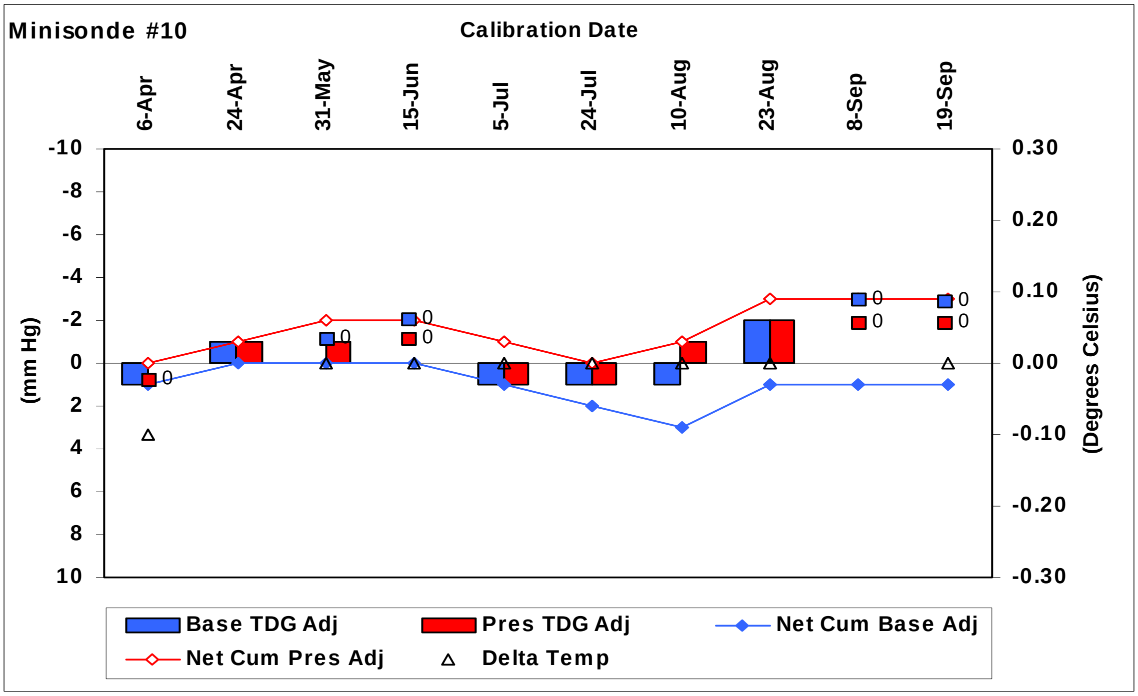


Figure 25. Control Chart for Hydrolab Minisonde Serial Number 32428 (#10).

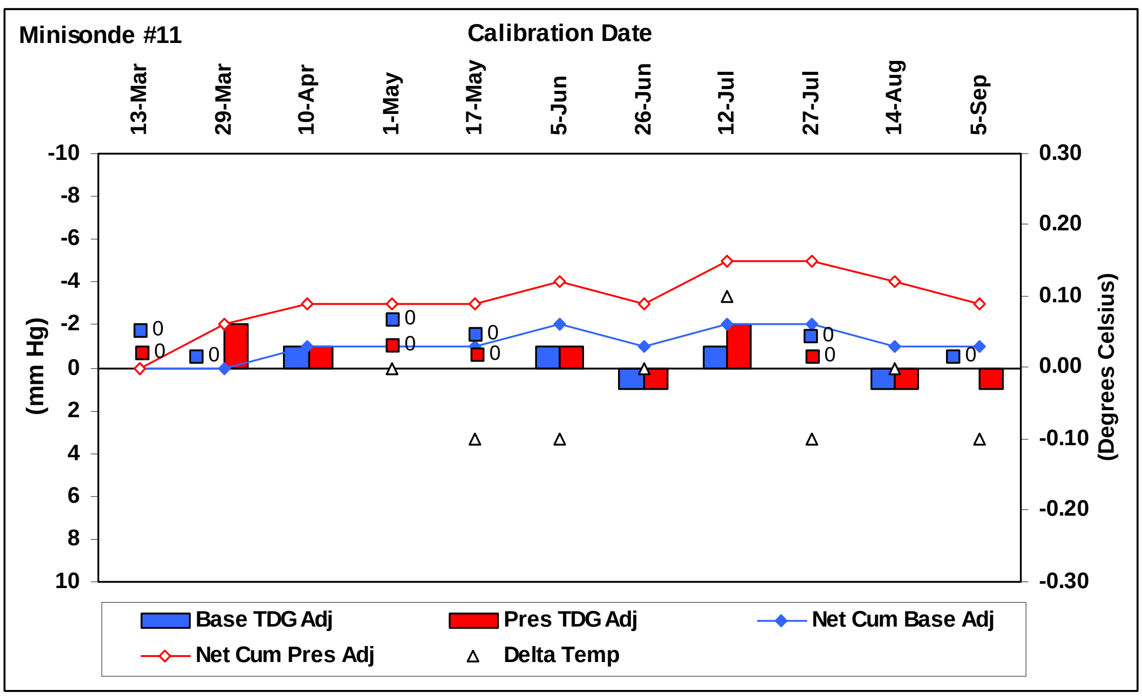


Figure 26. Control Chart for Hydrolab Minisonde Serial Number 32465 (#11).

l. Sonde #12.

This unit was utilized during the winter monitoring portion for temperature monitoring only. This instrument failed pre-deployment trials in the spring. It remained non-mission capable for the entire season. This unit is currently non-operational and its gas probe port is now capped and plugged. The oxygen sensor was substituted to keep another instrument running.

m. **Sonde #13.**

This instrument was used from May to August. With a single point of data outside of control (30 May) the instrument performed exceptionally. After August, it became non-mission capable when it was apparently damaged at Peck when this station was damaged.

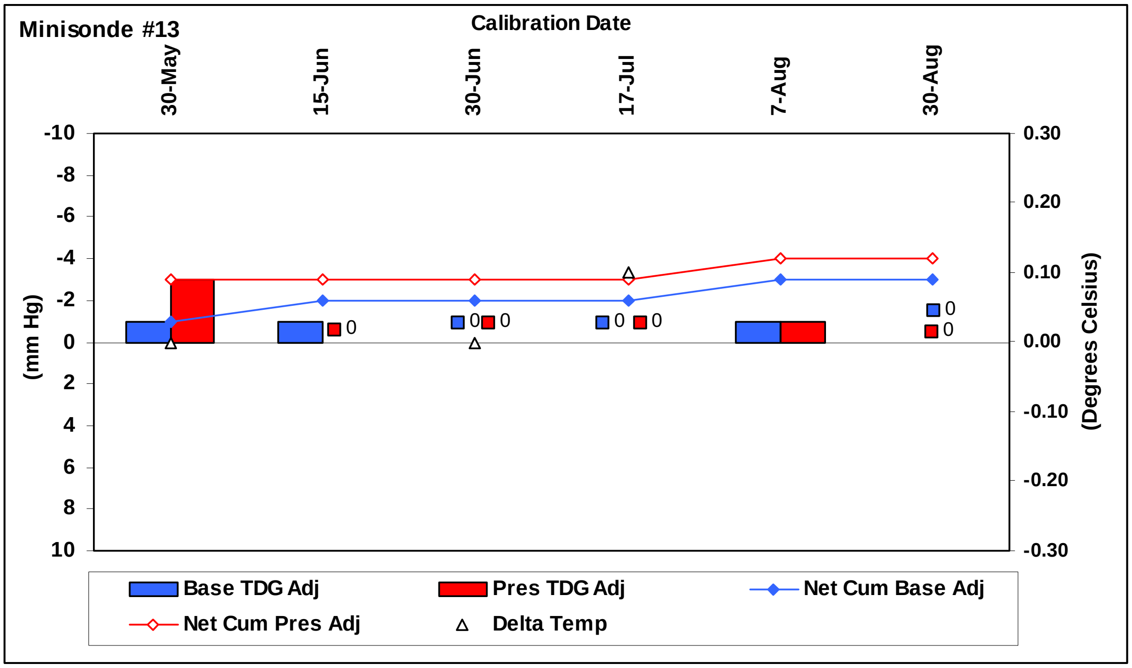


Figure 27. Control Chart for Hydrolab Minisonde Serial Number 32433 (#13).

n. **Sonde #14.**

This unit was used during the main season and performed within standards except in April. The instrument required a 3 mm Hg adjustment in April. This is not considered to be within CENWW's control limits but is still within the manufacturer's specifications. The error was discovered in April. During the April audit, it was determined that an error occurred in the barometric pressure reading from the mercury standard. This procedural error was corrected and the instrument was in standards the remaining portion of the year.

o. **Sonde #15.**

This instrument was not used in the FY 2000 monitoring season. It has an unstable pressure transducer and a usable DO sensor. It is still in a non-mission capable status. It will be overhauled in 2001.

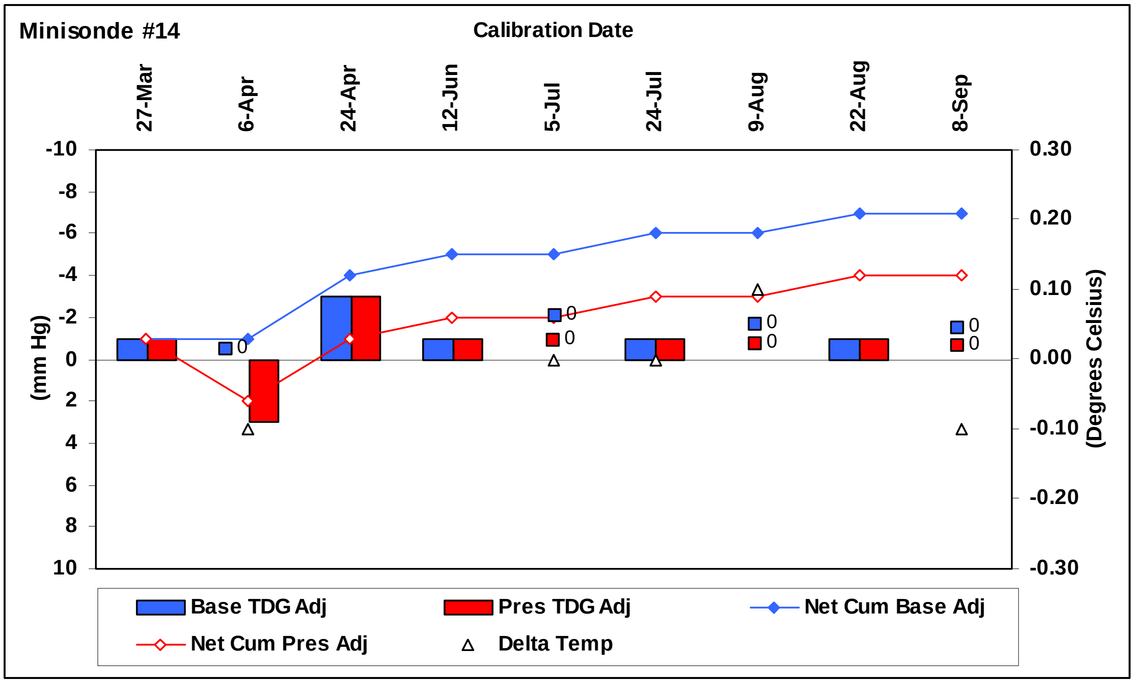


Figure 28. Control Chart for Hydrolab Minisonde Serial Number 32434 (#14).

p. Sonde #16.

This instrument performed quite well and was below the DQO's the entire year.

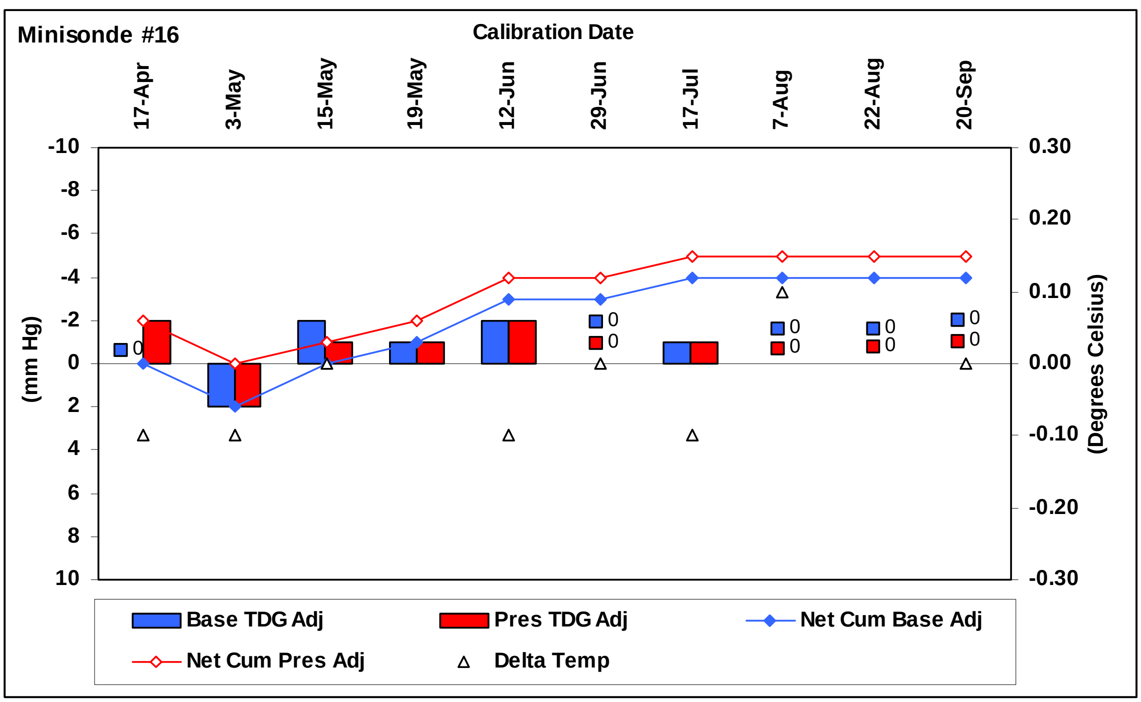


Figure 29. Control Chart for Hydrolab Minisonde Serial Number 32429 (#16).

q. Sonde #17.

This unit never passed QA/QC in the winter or the spring and was never deployed. It was sent to the manufacturer and was overhauled. It went through a test and evaluation period after coming back from the factory. It again failed to meet QA and only barely met specifications. It will function but it does meet the QA/QC for deployment. The manufacturer has not made additional repairs. The DO sensor is currently non-operational.

r. Sonde #18.

This unit started service in the month of March and performed consistently very well. In July, it was sent to the manufacturer for maintenance. It was tested in August and failed QC because the pressure transducer (TDG) was still outside the control limits. It is planned to send this unit back to the manufacturer for a complete overhaul. Until the July failure, the unit performed well and it is not planned to retire it until some time in 2006.

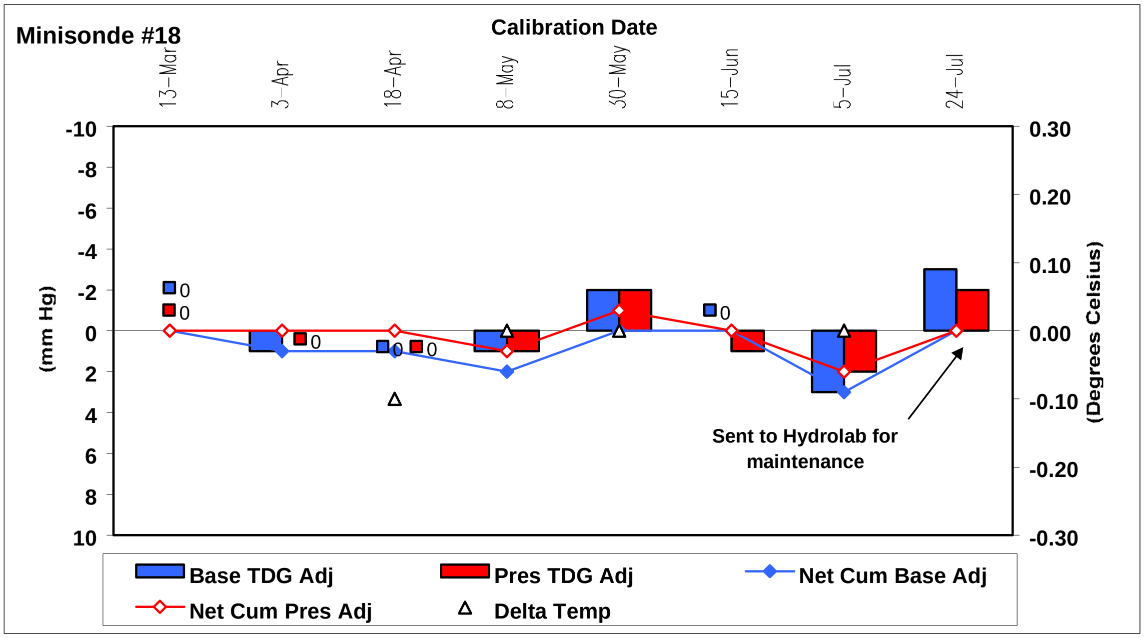


Figure 30. Control Chart for Hydrolab Minisonde Serial Number 32435 (#18).

s. Sonde #19.

This unit was used once in April and once in May. It is fairly new but the unit fails to calibrate properly. It requires repair but has not been repaired yet. We anticipated that it would be sent in for repair rather than replacement since it is only a few years old and has not seen much use.

t. Sonde #20.

This unit is one of the fleet's best sondes. It provided excellent service the entire season and provided better than required precision. The unit exceeded all specifications and QC limits. The unit is currently scheduled for an oxygen sensor rebuild and is expected to return to service in spring of 2001.

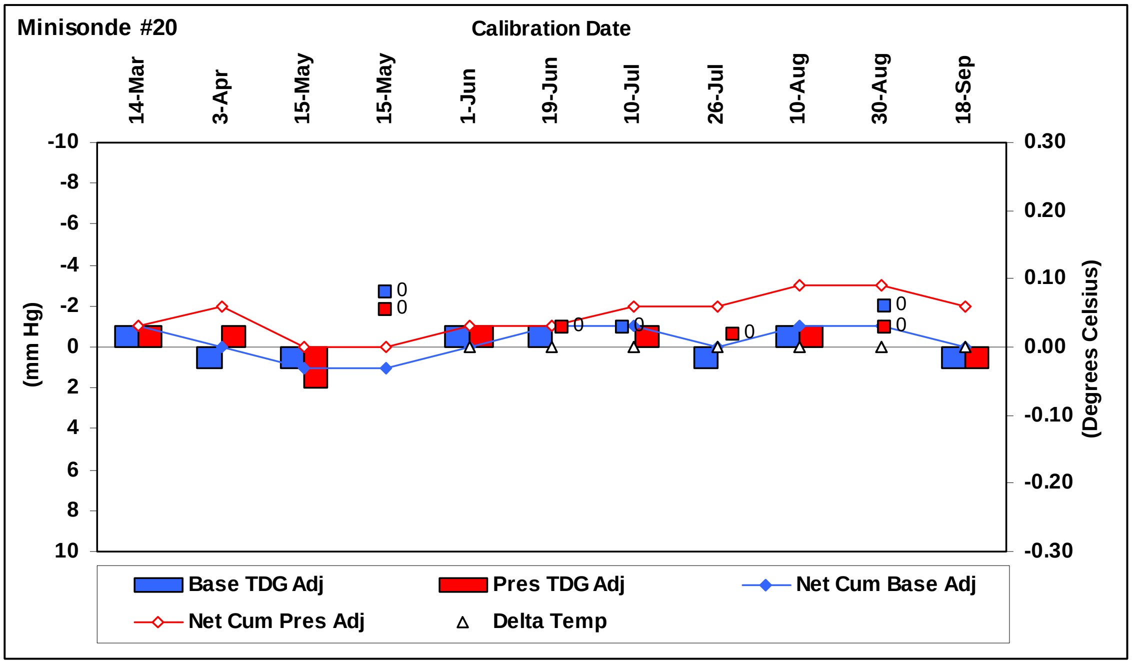


Figure 31. Control Chart for Hydrolab Minisonde Serial Number 32442 (#20).

u. Sonde #21.

This instrument performed exceptionally well with its TDG sensor. The temperature sensor has performed very well but appears to have drifted slightly downward. The temperature sensor is still currently within manufacturer's specifications.

v. Sonde #22.

The TDG sensor in this unit met specifications and passed QC limits throughout this season. Two outlying data points were observed of the standard but were still within the manufacturer's specifications. This is one of the newer units and has performed exceeding well this season.

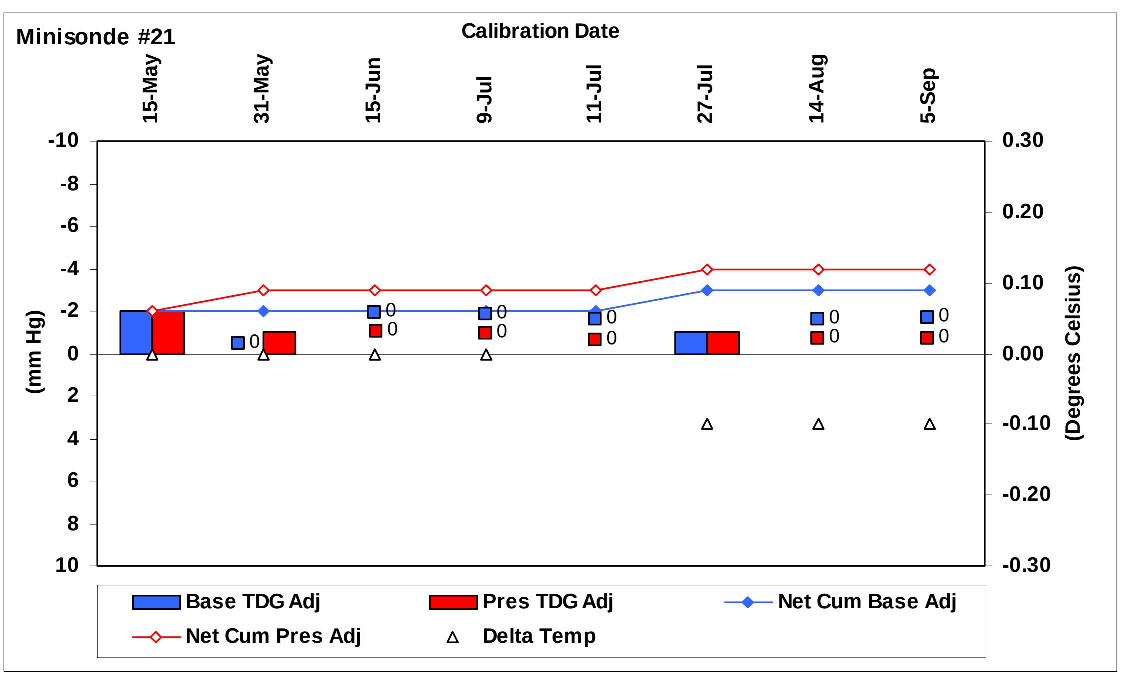


Figure 32. Control Chart for Hydrolab Minisonde Serial Number 32443 (#21).

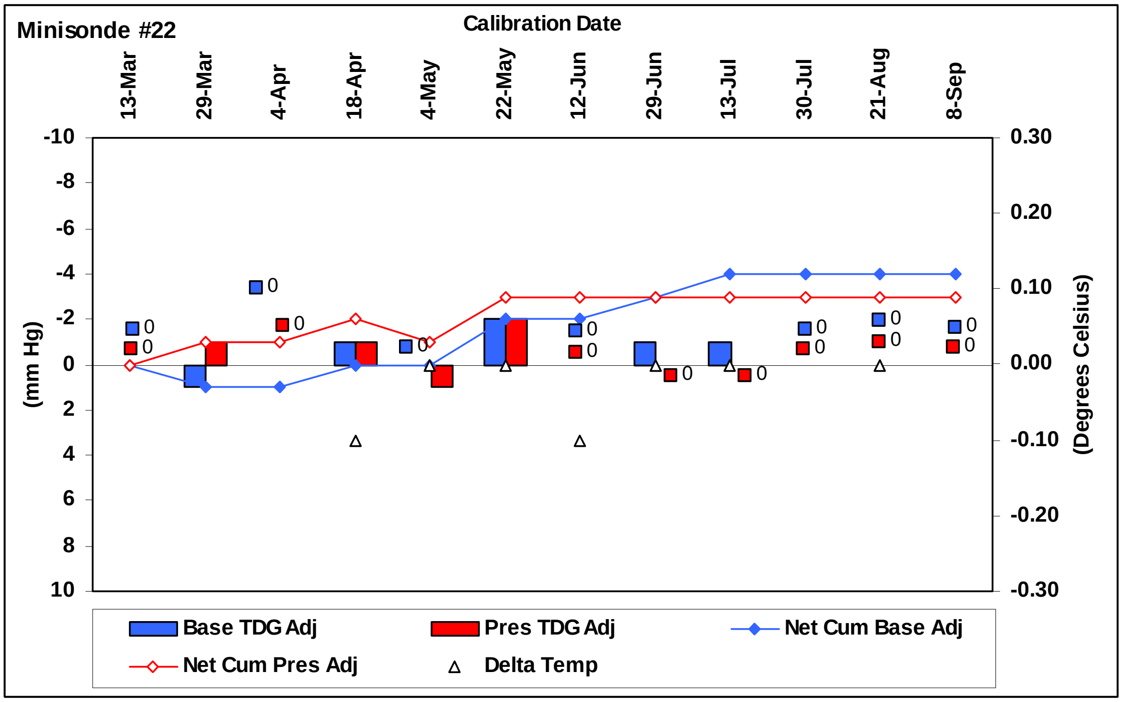


Figure 33. Control Chart for Hydrolab Minisonde Serial Number 32417 (#22).

w. Sonde #23.

This instrument is a new acquisition and was placed into service in September prior to going through trials due to lack of serviceable instruments. The instrument is one of the winter 2001 instruments and has proven to provide flawless data when measured against a standard.

x. Sonde #24.

This unit received severe water damage due to an O-ring failure and was written off as a total loss in February 2000.

y. Sonde #25.

This unit is a new acquisition and provided flawless TDG performance. The temperature sensor has been troublesome and failed QC on two occasions. The manufacturer's specification states that this thermister is just inside their specifications and will not warrant repair. This unit was not used in water year 2001 winter cycle and is scheduled for another temperature calibration at the factory.

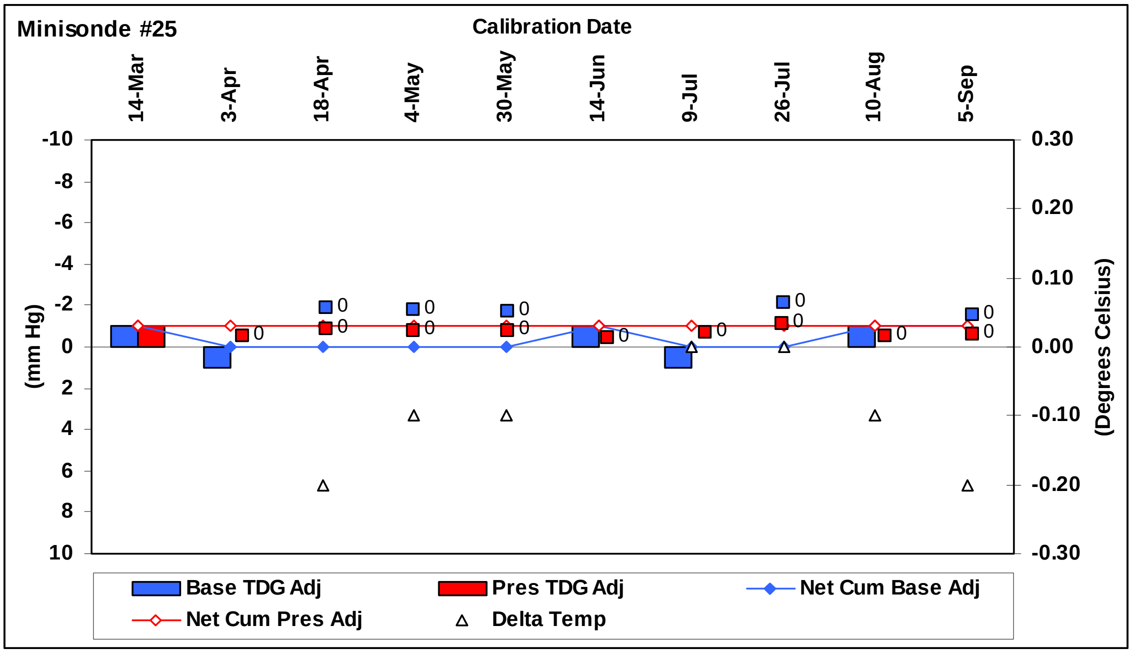


Figure 34. Control Chart for Hydrolab Minisonde Serial Number 36687 (#25).

z. Sonde #26.

This unit provided data within specifications for the entire water year. It appears that there was one data point outside control limits in early May. This may have been an anomaly since the error could not be repeated in the lab. Additional tests still did not render any reason for the dip in the lower control point. The rest of the year, it continued to provide temperature data within the manufacturer's specifications.

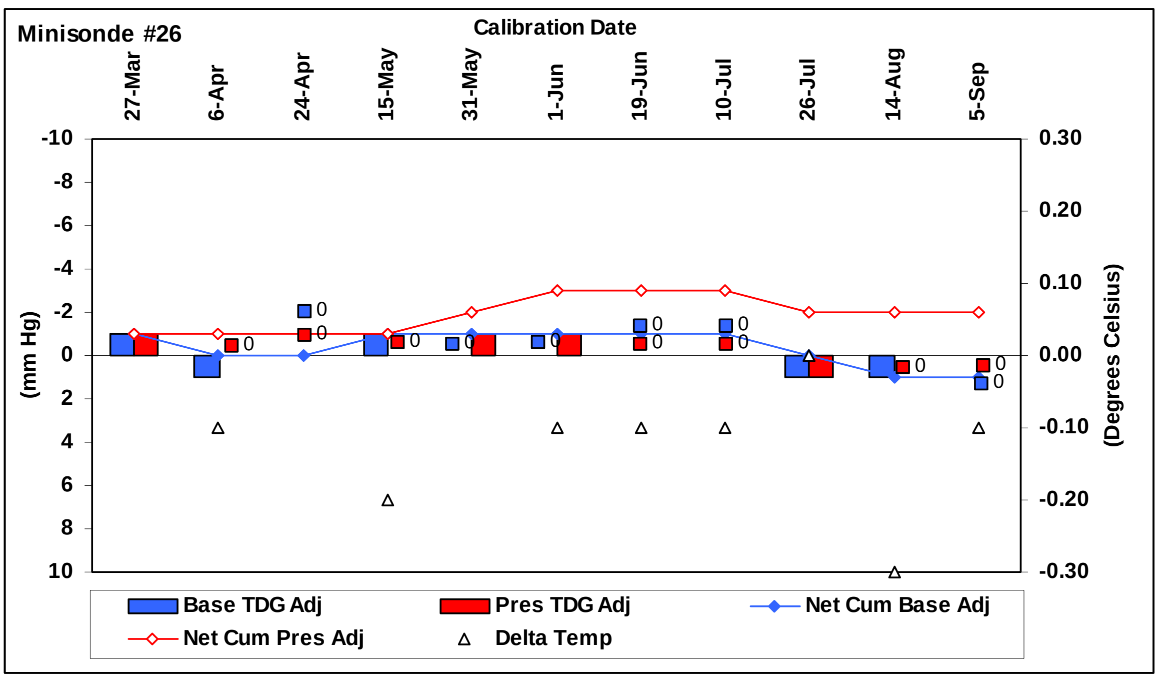


Figure 35. Control Chart for Hydrolab Minisonde Serial Number 36685 (#26).

aa. Sonde #27.

This unit is also a new acquisition and has performed well in the measurement of TDG pressure. As with other units in this batch (these are Minisonde mode 4a type sondes), the temperature probes are of lesser tolerances than the older units. This unit was kept in service until the end of the season because of the dwindling number of serviceable instruments. The temperature sensor was still within the manufacturer's specifications.

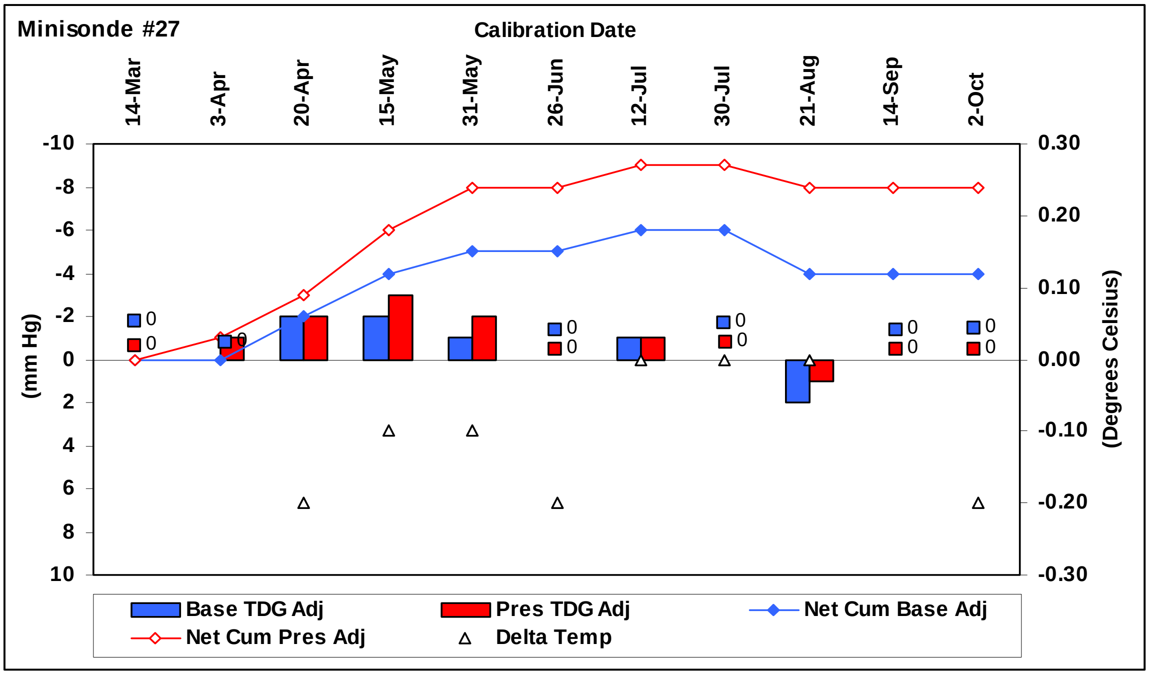


Figure 36. Control Chart for Hydrolab Minisonde Serial Number 36688 (#27).

bb. Sonde #28.

This instrument performed in the same manner as the sonde #27 instrument. Again, the thermister barely makes tolerances by manufacturer's specifications but does not meet the district QC limits, which reflect the DQO's. Again, this unit was kept in service due to the dwindling number of serviceable spares. It is currently used as a winter monitoring unit and its thermister is still barely within the manufacturer's specifications.

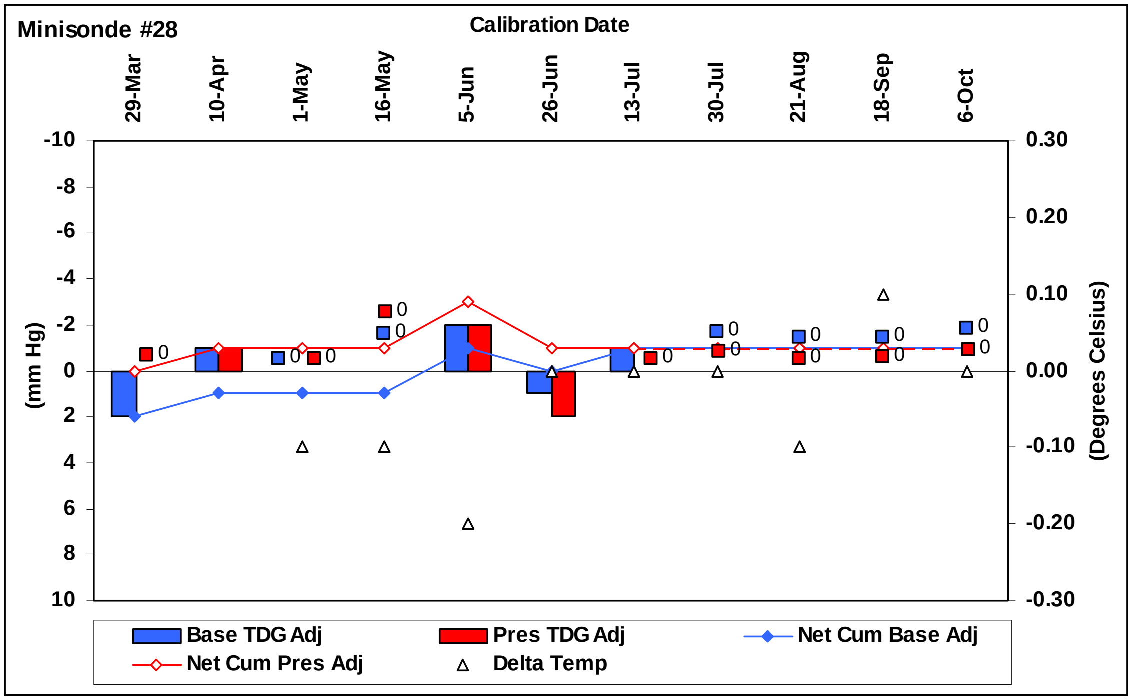


Figure 37. Control Chart for Hydrolab Minisonde Serial Number 36686 (#28).

DISCUSSION

This year, we focused on a critical evaluation of the instruments and spent considerable amounts of time evaluating the equipment for both the capability and operational aspects. After evaluation of the goals and objectives, it is very possible to obtain repeatable results for TDG within ±2 mm Hg of the standard when calibrated in the laboratory setting. In emergency situations, it may be possible to obtain tolerances of ±5 mm Hg in the field. Additional tests and evaluations would be required to calculate practical field-calibration precision levels. In practice, we have obtained this relative accuracy in field calibration. It is for this reason we recommend all calibrations take place in the laboratory with instruments.

In looking at making future improvements to instrumentation performance, we begin to ask what is reasonable and what is past the point of diminishing return. Improvements to the temperature precision and accuracy will increase the cost of the temperature sensor 10 times the current cost. This would include purchase and maintenance costs but would not reflect research and development (R&D) costs, which are not easy to estimate. The performance of TDG sensors is technologically at the extent of their design. Much more sensitive pressure transducers are available but cost and physical size of the devices make their adaptation problematic. Additionally, there is considerable cost associated with R&D. Any changes to the design of the TDG sensor would have to be in the software design. Since the sensors are coupled sondes with computational capability, improvements such as auto ranging and multi-point calibration could improve relative precision if non-standard curves are appropriate. All these improvements would provide a millimeter or two of improvement to the accuracy but probably no more than that.

In some instances, the station-specific charts reflect improvements or modifications made to the deployment stations or operating procedures. For example, the SOP's were modified in April and May 2000 to improve instrument precision. Heise instrumentation replaced Baumonometers and Sphygnometers as a means of pressurizing the sensor for precise calibration. Also, new barometer and temperature standards were purchased in late June 2000 and were incorporated into the system by mid-July. The resulting improvements to the precision of the instruments had a direct impact on the station QA/QC data. The relationships between instrument precision and station performance are visible on the charts. On many of the charts, there is an apparent decrease in data quality in May and from mid-June to mid-July. The reason for this apparent decrease is the 2-week lag time to replace all of the instruments in the system with those instruments calibrated utilizing the new procedures or standards. In all cases, the new standards resulted in better instrument precision and, therefore, better station performance.

There were many such improvements and changes made to the system throughout the year. For example, when damage to a deployment pipe prevented the retrieval of the in-place instrument, it became necessary to compare the instrument inside the pipe to a QC instrument deployed outside the pipe. Consequently, the in-place instrument remained in the pipe until repairs were made, causing some instruments to be deployed for several months rather than the scheduled 2-week cycle. This has clear implications for QC data collection. Other station pipes became filled with sediment at certain times of the year, requiring both instruments to be deployed outside the pipe. Lastly, failing or faulty instrument sensors can directly affect station data at times. It is not possible to completely filter the instrument performance data from the evaluation of the station data. Each of these events affected the station data in a unique way. A particular station chart may represent the cumulative effects of several such events, making it difficult to attribute disruptions in the trends to a particular source or to discern between the influence that an instrument has on the data in comparison to the influence of the station itself. In many cases, the instrument performance and modifications to the instrument calibration procedures affected the station comparison data to a greater extent than the actual station.

Future station improvements will focus on developing a station barometer calibration program, developing better instrument deployment methods, and improving circulation in and around the instruments.

REFERENCES CITED

Colt, J. 1984. Computation of dissolved gas concentrations in water as functions of temperature, salinity, and pressure: American Fisheries Society Special Publication 14. 154 p.

Jones, J. C., D. C. Tracey, and F. W. Sorensen, eds. 1991. Operating manual for the U.S. Geological Survey's data-collection system with the Geostationary Operational Environmental Satellite: U.S. Geological Survey Open-File Report 91-99. 237 p.

Tanner, D. Q., H. E. Harrison, and S. W. McKenzie. 1996. Total dissolved gas, barometric pressure, and water temperature data, lower Columbia River, Oregon and Washington, 1996: U.S. Geological Survey Open-File Report 96-662A. 85 p.

U.S. Environmental Protection Agency. 1986, Quality criteria for water: Washington, D.C., EPA-440-5-86-001.

COPY AND USE PRIVLIGES

FULL CITATION

Heaton, Russell D., III; Timothy Seiple; Gary Slack; and Thomas D. Miller. 2001. Quality Assurance and Quality Control for Total Dissolved Gas Monitoring - Lower Snake River, Washington; Clearwater River, Idaho; and Columbia River, Oregon and Washington, February 2001. Done by the Walla Walla District Hydrology Section: Reservoir Regulation Team, 201 N. 3rd Avenue, Walla Walla, Washington, and HDR Engineering, Inc., 2805 St. Andrews Loop, Suite A, Pasco, Washington, for the U.S. Army Corps of Engineers, Walla Walla District under Contract DACW68-00-D-001, Task Order No. 1, Walla Walla Washington.
85 pages.

DISCLAIMER

The use of models, brand names, or trade names does not constitute a recommendation or endorsement of the United State Government, Department of Defense, U.S. Army, or the Corps of Engineers. They are merely mentioned in the pursuit of scientific repeatability.

APPENDIX A

SONDE MAINTENANCE AND CALIBRATION RECORD

SONDE MAINTENANCE AND CALIBRATION RECORD (ER1130-2-234 & ER130-2-415)	1. MINISONDE ADMIN. #	2. HYDROLAB SERIAL #	3. BARCODE #	4. DATA SHEET COMPLETE (Initial when compelte) ______

SECTION 1 - PRE-DEPLOYMENT SONDE CALIBRATION

5. DATE / 6. TIME	7. WALL BAROMETER	8. SURVEYOR 4 Bar	9. TDG MEMBRANE (check and circle all that apply) Dried Leak Check: Breath / Pressure Replaced	
10. TDG STANDARD	11. Pre-Cal Base TDG	12. Pre-Cal Pres TDG	13. Cal'd Base TDG	14. Cal'd Pres TDG
15. Dissolved Oxygen Membrane (circle) *Replaced*: Yes / No *24-hour Soak*: Yes / No		16. Dissolved Oxygen Standards Used To Calibrate Sonde Air (Bar) = ______ mm/Hg **OR** Winkler = ______ mg/l		
17. DO Lab Calibration (*Ambient Air Method*): BAR ______ mm, DO sat. = ______ % DO = ______ mg/l		18. DO Lab Calibration (*Winkler Titration Method*): BAR ______ mm/Hg, DO mg/l = ______ **AND** DO sat. = ______ %		
19. NBS Temp:	**NOTES:**			
20. Sonde Temp:				

SECTION 2 - STATION INFORMATION

21. STATION NAME	22. DATE	23. OFFICIAL TIME h (GMT)	24. DCP TIME h (GMT)	25. CHARGER TYPE	26. CHARGER STATUS
27. BATTERY DATE: /		31. BAROM. BARCODE #	32. SURVEYOR 4 BAR mm	33. STATION BAR (Initial) mm	34. STATION BAR (Cal'd) mm
28. BATTERY VOLTAGE: v					
29. FUSE STATUS ( )		35. STATION DUE DATE	36. TECHNICIAN NAME	STATION NOTES:	
30. SUTRON STATUS ( )					

SECTION 3 - SONDE DEPLOYMENT DATA

37. SITE ARRIVAL TIME	38. DO Field Calibration (*Ambient Air Method*): BAR ______ mm, DO% = ______ % DO = ______ mg/l		39. DO Field Calibration (*Winkler Titration Method*): BAR ______ mm, DO mg/l = ______ DO sat. = ______ %		
40. PRE-DEPLOYMENT HYDROLAB CHECKS Operation ( ) TDG Response ( ) DO Field Calibrated ( )		41. DEPLOYMENT TIME In-Pipe / Out-of-Pipe	42. STABLE READINGS ( )	43. TIME OF QC READINGS	
Target TDG	44. QA/QC SONDE	45. TDG	46. DO %sat.	47. DO mg/l	48. TEMP °C
Target DO mg/L	49. IN PLACE SONDE	50. TDG	51. DO %sat.	52. DO mg/l	53. TEMP °C
54. TDG CHECK (final)	55. CHARGER STATUS (final)		56. DEPARTURE TIME	57. TECHNICIAN	

ADDITIONAL NOTES:

SECTION 4 - POST-DEPLOYMENT SONDE CALIBRATION CHECK

58. Proper Data Sheet Yes / No	59. Check Date / Time	60. WALL BAROMETER	61. SURVEYOR 4 Bar	62. Physical Condition:	63. Sonde Cleaned? Yes / No
66. DO Lab Check (*Ambient Air Method*): BAR ______ mm, DO sat. = ______ % DO = ______ mg/l			67. TDG STANDARD mm/Hg	68. Baseline TDG Check	69. Pressurized Check
70. DO Lab Calibration (*Winkler Titration Method*): BAR ______ mm/Hg, DO mg/l = ______ **AND** DO sat. = ______ %				71. NBS Standard °C	72. Sonde Temp Check °C

ADDITIONAL NOTES:

MCQO - McNary Forebay, OR, **MCQW** - McNary Forebay, WA, **MCPW** - McNary Tailwater, **PAQW** - Pasco Station, **IHR** - Ice Harbor Forebay, **IDSW** - Ice Harbor Tailwater, **LMN** - Lower Monumental Forebay, **LMNW** - Lower Monumental Tailwater, **LGS** - Little Goose Forebay, **LGSW** - Little Goose Tailwater, **LWG** Lower Granite Forebay, **LGNW** - Lower Granite Tailwater, **LEWI** - Lewiston, **ANQW** - Anatone, **PEKI** - Peck, **DWQI** - Dworshak

APPENDIX B

MONTHLY SORTED SONDE DATA

Monthly Sorted Sonde Data

Calibration Date by	Calibration Date	Sonde Admin #	Delta Base TDG	Delta Press TDG	Delta Temp
March 2000					
	3/13/00	7	0	0	
	3/13/00	9	0	0	
	3/13/00	11	0	0	
	3/13/00	18	0	0	
	3/13/00	22	0	0	
	3/14/00	20	1	1	
	3/14/00	25	1	1	
	3/14/00	27	0	0	
	3/27/00	1	-2	-2	
	3/27/00	10	1	-5	
	3/27/00	14	1	1	
	3/27/00	26	1	1	
	3/29/00	5	0	0	
	3/29/00	9	-2	0	
	3/29/00	11	0	2	
	3/29/00	22	-1	1	
	3/29/00	28	-2	0	
April 2000					
	4/ 3/00	7	0	1	
	4/ 3/00	18	-1	0	
	4/ 3/00	20	-1	1	
	4/ 3/00	25	-1	0	
	4/ 3/00	27	0	1	
	4/ 4/00	1	0	1	
	4/ 4/00	22	0	0	
	4/ 6/00	9	0	0	0.00
	4/ 6/00	10	-1	0	0.10
	4/ 6/00	14	0	-3	0.10

Calibration Date by	Calibration Date	Sonde Admin #	Delta Base TDG	Delta Press TDG	Delta Temp
	4/ 6/00	26	-1	0	0.10
	4/10/00	3	1	2	
	4/10/00	8	1	2	
	4/10/00	11	1	1	
	4/10/00	28	1	1	
	4/17/00	2	4	4	0.00
	4/17/00	5	1	1	0.00
	4/17/00	16	0	2	0.10
	4/18/00	1	1	1	0.10
	4/18/00	18	0	0	0.10
	4/18/00	22	1	1	0.10
	4/18/00	25	0	0	0.20
	4/20/00	3	1	1	0.10
	4/20/00	7	1	1	0.10
	4/20/00	27	2	2	0.20
	4/24/00	9	0	0	
	4/24/00	10	1	1	
	4/24/00	14	3	3	
	4/24/00	26	0	0	
May 2000					
	5/ 1/00	8	0	0	0.10
	5/ 1/00	11	0	0	0.00
	5/ 1/00	15	5	9	0.10
	5/ 1/00	28	0	0	0.10
	5/ 3/00	2	-1	-1	0.00
	5/ 3/00	6	-2	-2	0.00
	5/ 3/00	16	-2	-2	0.10
	5/ 4/00	1	-1	-1	0.10
	5/ 4/00	5	-1	-1	0.00
	5/ 4/00	22	0	-1	0.00
	5/ 4/00	25	0	0	0.10
	5/ 8/00	3	-2	-2	0.00

Calibration Date by	Calibration Date	Sonde Admin #	Delta Base TDG	Delta Press TDG	Delta Temp
	5/ 8/00	7	-3	-3	0.00
	5/ 8/00	13	-5	0	0.00
	5/ 8/00	18	-1	-1	0.00
	5/15/00	16	2	1	0.00
	5/15/00	20	-1	-2	
	5/15/00	20	0	0	
	5/15/00	21	2	2	0.00
	5/15/00	26	1	0	0.20
	5/15/00	27	2	3	0.10
	5/16/00	28	0	0	0.10
	5/17/00	8	-1	-1	
	5/17/00	11	0	0	0.10
	5/17/00	15	0	1	0.00
	5/18/00	2	2	2	0.10
	5/18/00	6	2	2	0.00
	5/19/00	16	1	1	
	5/22/00	1	1	2	
	5/22/00	5	2	2	
	5/22/00	22	2	2	0.00
	5/30/00	3	1	2	0.00
	5/30/00	7	4	4	0.00
	5/30/00	13	1	3	0.00
	5/30/00	18	2	2	0.00
	5/30/00	25	0	0	0.10
	5/31/00	10	0	1	0.00
	5/31/00	21	0	1	0.00
	5/31/00	26	0	1	
	5/31/00	27	1	2	0.10
June 2000					
	6/ 1/00	8	2	1	0.00
	6/ 1/00	20	1	1	0.00
	6/ 1/00	26	0	1	0.10

Calibration Date by	Calibration Date	Sonde Admin #	Delta Base TDG	Delta Press TDG	Delta Temp
	6/ 5/00	2	0	1	0.00
	6/ 5/00	11	1	1	0.10
	6/ 5/00	15	0	0	0.10
	6/ 5/00	28	2	2	0.20
	6/12/00	1	-3	-3	0.10
	6/12/00	5	0	0	0.00
	6/12/00	14	1	1	
	6/12/00	16	2	2	0.10
	6/12/00	22	0	0	0.10
	6/14/00	3	0	0	
	6/14/00	7	0	0	
	6/14/00	25	1	0	
	6/15/00	7	0	0	
	6/15/00	13	1	0	
	6/15/00	18	0	-1	
	6/15/00	21	0	0	0.00
	6/15/00	10	0	0	0.00
	6/19/00	8	0	0	0.00
	6/19/00	20	1	0	0.00
	6/19/00	26	0	0	0.10
	6/26/00	2	0	-1	0.10
	6/26/00	11	-1	-1	0.00
	6/26/00	15	-2	-1	0.00
	6/26/00	27	0	0	0.20
	6/26/00	28	-1	-2	0.00
	6/29/00	1	1	1	
	6/29/00	1	1	1	0.10
	6/29/00	3	2	3	0.00
	6/29/00	5	-1	-1	0.00
	6/29/00	16	0	0	0.00
	6/29/00	22	1	0	0.00
	6/30/00	13	0	0	0.00

Calibration Date by	Calibration Date	Sonde Admin #	Delta Base TDG	Delta Press TDG	Delta Temp
July 2000					
	7/ 5/00	7	-1	0	-0.10
	7/ 5/00	10	-1	-1	0.00
	7/ 5/00	14	0	0	0.00
	7/ 5/00	18	-3	-2	0.00
	7/ 9/00	21	0	0	0.00
	7/ 9/00	25	-1	0	0.00
	7/10/00	8	0	0	0.10
	7/10/00	20	0	1	0.00
	7/10/00	26	0	0	0.10
	7/11/00	21	0	0	
	7/12/00	2	1	1	0.10
	7/12/00	11	1	2	-0.10
	7/12/00	27	1	1	0.00
	7/13/00	5	0	0	0.00
	7/13/00	22	1	0	0.00
	7/13/00	28	1	0	0.00
	7/17/00	1	-2	-1	0.10
	7/17/00	3	-2	-2	0.00
	7/17/00	13	0	0	-0.10
	7/17/00	16	1	1	0.10
	7/24/00	7	0	0	0.10
	7/24/00	10	-1	-1	0.00
	7/24/00	14	1	1	0.00
	7/24/00	18	3	2	
	7/26/00	8	-1	-1	0.00
	7/26/00	20	-1	0	0.00
	7/26/00	25	0	0	0.00
	7/26/00	26	-1	-1	0.00
	7/27/00	2	0	0	0.10
	7/27/00	11	0	0	0.10
	7/27/00	21	1	1	0.10

Calibration Date by	Calibration Date	Sonde Admin #	Delta Base TDG	Delta Press TDG	Delta Temp
	7/30/00	5	0	0	0.00
	7/30/00	22	0	0	
	7/30/00	27	0	0	0.00
	7/30/00	28	0	0	0.00
August 2000					
	8/ 7/00	1	1	1	
	8/ 7/00	3	0	0	
	8/ 7/00	13	1	1	
	8/ 7/00	16	0	0	-0.10
	8/ 9/00	14	0	0	-0.10
	8/10/00	7	0	0	0.00
	8/10/00	8	0	0	
	8/10/00	10	-1	1	0.00
	8/10/00	20	1	1	0.00
	8/10/00	25	1	0	0.10
	8/14/00	2	0	0	0.10
	8/14/00	11	-1	-1	0.00
	8/14/00	21	0	0	0.10
	8/14/00	26	-1	0	0.30
	8/21/00	5	-1	-1	0.10
	8/21/00	22	0	0	0.00
	8/21/00	27	-2	-1	0.00
	8/21/00	28	0	0	0.10
	8/22/00	7	0	0	
	8/22/00	14	1	1	
	8/22/00	16	0	0	
	8/23/00	10	2	2	0.00
	8/24/00	8	1	1	
	8/30/00	1	0	0	0.10
	8/30/00	13	0	0	
	8/30/00	20	0	0	0.00
September 2000					

Calibration Date by	Calibration Date	Sonde Admin #	Delta Base TDG	Delta Press TDG	Delta Temp
	9/ 5/00	2	0	-1	
	9/ 5/00	11	0	-1	0.10
	9/ 5/00	21	0	0	0.10
	9/ 5/00	25	0	0	0.20
	9/ 5/00	26	0	0	0.10
	9/ 7/00	3	0	0	0.00
	9/ 8/00	8	0	0	0.00
	9/ 8/00	10	0	0	
	9/ 8/00	14	0	0	0.10
	9/ 8/00	22	0	0	
	9/14/00	7	0	0	
	9/14/00	27	0	0	
	9/18/00	20	-1	-1	0.00
	9/18/00	23	0	0	0.00
	9/18/00	28	0	0	-0.10
	9/19/00	2	0	0	0.00
	9/19/00	10	0	0	0.00
	9/20/00	16	0	0	0.00
	9/21/00	7	0	0	0.10
October 2000					
	10/ 2/00	27	0	0	0.20
	10/ 6/00	23	0	0	0.00
	10/ 6/00	28	0	0	0.00

APPENDIX C

MONTHLY SORTED STATION DATA

Monthly Sorted Station Data

Deployment Date by Month	Deployment Date	Station ID	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
March 2000						
	3/14/00	MCQO	22	27	-4	0.00
	3/14/00	MCQW	11	20	0	0.00
	3/14/00	MCPW	9	25		
	3/15/00	IDSW	18	1	6	-0.07
	3/15/00	IHR	7	10	-1	-0.01
	3/16/00	DWQI	25	26	0	0.03
	3/16/00	LWG	27	5	0	0.05
	3/16/00	LGNW	20	14	5	-0.04
	3/28/00	MCQW	10	11	1	0.02
	3/28/00	MCQO	14	22	-2	0.00
	3/28/00	MCPW	26	9	-1	0.05
	3/28/00	PAQW	1	28	0	-0.10
	3/29/00	IDSW	9	18	3	-0.11
	3/30/00	IHR	22	7	-3	0.00
	3/31/00	DWQI	5	25	-2	-0.20
	3/31/00	LGNW	11	20	0	0.00
	3/31/00	LWG	28	27	1	-0.11
April 2000						
	4/ 4/00	PAQW	18	1	4	-0.06
	4/ 4/00	IDSW	20	9	2	0.06
	4/ 4/00	IHR	7	22	2	-0.02
	4/ 4/00	MCQW	1	10	-4	-0.08
	4/ 5/00	MCQO	22	14	-6	-0.02
	4/ 5/00	MCPW	25	26	1	-0.02
	4/ 7/00	LGNW	14	11	-1	0.04
	4/ 7/00	LGS	10	3	0	-0.10
	4/ 7/00	LGSW	26	8	-3	-0.04
	4/ 7/00	LWG	9	28	0	-0.10
	4/10/00	LMNW	3	19		
	4/10/00	LMN	27	2	0	0.03
	4/11/00	DWQI	8	5	3	0.12
	4/11/00	LEWI	28	16	-1	0.16
	4/11/00	ANQW	11	6	-7	-0.09
	4/18/00	PAQW	2	18	0	0.06

Deployment Date by Month	Deployment Date	Station ID	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
	4/18/00	ANQW	16	1	2	0.05
	4/19/00	LMN	22	27	2	-0.01
	4/19/00	IDSW	5	20	0	-0.03
	4/19/00	LMNW	1	3	1	0.08
	4/19/00	IHR	25	7	1	0.01
	4/21/00	LGS	18	10	1	-0.08
	4/21/00	LGSW	3	26	-1	-0.06
	4/21/00	LGNW	7	14	2	0.00
	4/21/00	LWG	27	9	2	0.11
	4/25/00	DWQI	9	8	1	-0.13
	4/26/00	LEWI	26	28	6	-0.06
	4/26/00	DWQI	14	9	2	0.10
	4/26/00	ANQW	10	11	0	0.05
May 2000						
	5/ 2/00	MCQW	11	16	1	-0.05
	5/ 2/00	PAQW	8	2	0	0.01
	5/ 2/00	MCPW	15	19	3	0.05
	5/ 2/00	MCQO	28	6	-2	0.15
	5/ 3/00	IHR	16	25	0	0.00
	5/ 4/00	LMNW	2	1	0	0.05
	5/ 4/00	LMN	6	22	3	-0.10
	5/ 5/00	LGSW	5	3	-1	-0.01
	5/ 5/00	LGNW	1	7	-2	-0.01
	5/ 5/00	LGS	25	18	-1	0.07
	5/ 5/00	LWG	22	27	-4	-0.01
	5/ 9/00	LEWI	13	26	0	-0.10
	5/ 9/00	PEKI	7	20	-4	0.07
	5/ 9/00	DWQI	3	14	-1	-0.09
	5/ 9/00	ANQW	18	10	-1	-0.01
	5/16/00	MCQW	21	11	-3	0.04
	5/16/00	MCQO	27	28	0	-0.14
	5/16/00	MCPW	26	15	-4	0.03
	5/17/00	IHR	28	16	-1	0.08
	5/17/00	PAQW	16	8	-1	0.00
	5/17/00	IDSW	20	19	2	0.06
	5/18/00	LMNW	8	2	4	0.05
	5/18/00	LMN	20	6	3	0.07
	5/19/00	LGNW	2	1	1	0.00

Deployment Date by Month	Deployment Date	Station ID	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
	5/19/00	LGSW	11	5	14	0.03
	5/19/00	LWG	6	22	3	-0.10
	5/19/00	LGS	15	25	5	-0.05
	5/23/00	DWQI	22	3	1	0.04
	5/23/00	PEKI	16	7	3	0.02
	5/23/00	ANQW	1	18	0	0.06
	5/24/00	LEWI	5	13	2	0.03
	5/31/00	LMNW	10	8	6	-0.02
	5/31/00	MCPW	7	26	-2	0.01
	5/31/00	PAQW	13	10	-1	-0.10
	5/31/00	MCQO	25	27	-4	0.04
	5/31/00	MCQW	3	21	1	-0.07
June 2000						
	6/ 1/00	IDSW	26	19	-4	-0.10
	6/ 1/00	IHR	21	28	1	-0.10
	6/ 1/00	LMN	18	20	3	0.02
	6/ 2/00	LGNW	27	2	3	0.02
	6/ 2/00	LWG	26	6	-1	0.15
	6/ 2/00	LGS	20	15		0.04
	6/ 2/00	LGSW	8	11	2	0.11
	6/ 6/00	DWQI	2	22	3	0.01
	6/ 6/00	ANQW	15	1	10	-0.05
	6/ 7/00	LEWI	28	5	0	0.10
	6/13/00	MCQO	22	25	-1	-0.03
	6/13/00	MCQW	1	3	-5	0.03
	6/13/00	MCPW	5	7	-2	-0.06
	6/14/00	PAQW	16	13	-2	0.12
	6/14/00	IDSW	7	19	1	0.11
	6/14/00	IHR	14	21	0	0.00
	6/15/00	LMNW	25	10	-1	0.08
	6/15/00	LMN	3	18	2	-0.02
	6/16/00	LGS	18	20	1	-0.01
	6/16/00	LWG	7	26	-3	-0.07
	6/16/00	PEKI	11	16	3	-0.04
	6/16/00	LGSW	13	8	-1	-0.15
	6/16/00	LGNW	10	27	6	0.02
	6/20/00	PEKI	8	11	-2	0.05
	6/20/00	LEWI	20	28	1	-0.03

Deployment Date by Month	Deployment Date	Station ID	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
	6/20/00	DWQI	21	2	-5	0.00
	6/21/00	ANQW	26	15	-7	0.04
	6/27/00	MCQO	27	22	0	-0.17
	6/27/00	MCQW	2	1	1	0.12
	6/27/00	MCPW	11	5	-4	0.04
	6/28/00	PAQW	15	16	4	-0.06
	6/29/00	LMN	22	3	0	0.00
	6/29/00	LMNW	28	25	1	0.02
	6/29/00	IDSW	1	19	1	0.02
	6/29/00	IHR	5	14	1	-0.11
	6/30/00	LWG	1	7	0	0.00
	6/30/00	LGSW	3	13	2	0.05
	6/30/00	LGNW	16	10	0	0.09
	6/30/00	LGS	13	18	3	-0.02
July 2000						
	7/ 6/00	DWQI	18	21	0	0.01
	7/ 6/00	LEWI	10	20	0	-0.09
	7/ 6/00	ANQW	7	26	-4	0.06
	7/ 6/00	PEKI	14	8	-1	-0.01
	7/11/00	MCPW	26	11	-5	0.02
	7/11/00	MCQO	8	27	-4	0.03
	7/11/00	MCQW	20	2	0	-0.21
	7/11/00	PAQW	25	15		
	7/12/00	IDSW	21	19	-1	0.09
	7/12/00	IHR	21	5	-1	0.01
	7/13/00	LMNW	11	28	6	0.00
	7/13/00	LMN	2	22	0	0.04
	7/14/00	LWG	22	1	0	-0.02
	7/14/00	LGNW	27	16	0	-0.04
	7/14/00	LGSW	5	3	0	-0.03
	7/14/00	LGS	28	13	0	-0.12
	7/18/00	DWQI	1	18	0	-0.03
	7/18/00	LEWI	13	10	-1	-0.09
	7/18/00	PEKI	3	14	1	-0.06
	7/19/00	ANQW	16	7	-1	0.08
	7/25/00	MCQO	7	8	0	-0.01
	7/25/00	MCQW	10	20	-3	-0.02
	7/25/00	MCPW	14	26	-4	0.01

Deployment Date by Month	Deployment Date	Station ID	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
	7/26/00	PAQW	18	25	0	-0.12
	7/27/00	LMNW	8	11	-1	0.06
	7/27/00	IDSW	25	19		
	7/27/00	IHR	20	21	0	0.05
	7/28/00	LGSW	11	5	0	0.03
	7/28/00	LWG	2	22	0	-0.02
	7/28/00	LGNW	26	27	1	-0.03
	7/28/00	LGS	21	28	0	-0.05
	7/30/00	LEWI	5	13	0	0.05
	7/30/00	ANQW	27	16		
	7/31/00	PEKI	28	3	0	0.13
	7/31/00	DWQI	22	1	1	0.02
August 2000						
	8/ 9/00	MCQW	1	10	-1	-0.02
	8/ 9/00	MCPW	3	14	0	-0.07
	8/ 9/00	MCQO	13	7	1	-0.11
	8/ 9/00	IDSW	16	25	1	-0.13
	8/ 9/00	IHR	14	20	7	0.14
	8/10/00	LMN	10	19	0	0.00
	8/10/00	LMNW	7	8	0	0.02
	8/11/00	LWG	25	2	0	-0.05
	8/11/00	LGSW	8	11	0	0.01
	8/11/00	LGNW	20	26	0	0.00
	8/15/00	PEKI	11	28	1	-0.11
	8/15/00	DWQI	2	22		
	8/16/00	LEWI	21	5	0	0.00
	8/16/00	ANQW	26	27	-1	-0.10
	8/22/00	IDSW	22	16	0	0.01
	8/22/00	LMN	27	10	0	-0.11
	8/22/00	LMNW	5	7	1	-0.15
	8/22/00	IHR	28	14	-5	0.07
	8/23/00	LGS	10	19	0	-0.03
	8/23/00	LGSW	7	8	0	-0.04
	8/23/00	LWG	16	25	2	-0.02
	8/23/00	LGNW	14	20	0	0.04
	8/24/00	MCQW	8	1	0	0.01
	8/30/00	PEKI	13	11	0	0.08
	8/30/00	DWQI	1	2	0	-0.04

Deployment Date by Month	Deployment Date	Station ID	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
	8/30/00	ANQW	20	26	0	-0.05
September 2000						
	9/ 6/00	MCQO	11	19	-3	0.06
	9/ 6/00	PAQW	25	17	0	0.02
	9/ 6/00	MCPW	2	3	-1	0.02
	9/ 6/00	MCQW	21	8	0	-0.01
	9/ 7/00	LGNW	26	14	-1	-0.02
	9/ 7/00	LGS	3	10	0	-0.04
	9/ 7/00	LGSW	16	7	1	-0.02
	9/ 8/00	LMN	8	27	0	0.02
	9/ 8/00	IHR	22	28	-2	-0.06
	9/ 8/00	LMNW	14	23	0	0.08
	9/ 8/00	IDSW	10	22	3	0.00
	9/14/00	ANQW	7	20	4	0.09
	9/14/00	DWQI	27	1	4	0.02
	9/19/00	MCPW	28	2	0	0.02
	9/19/00	IDSW	20	10	0	-0.01
	9/19/00	MCQO	10	11	0	0.06
	9/19/00	IHR	23	22	-4	-0.06
	9/19/00	MCQW	2	21	-1	-0.04
	9/21/00	DWQI	7	27	0	-0.04
October 2000						
	10/ 6/00	MCPW	27	28	0	-0.07
	10/ 6/00	MCQW	23	2	0	0.01
	10/ 6/00	MCQO	28	10	-2	0.10

APPENDIX D

SONDE-SPECIFIC DATA

Sonde Specific Data

Sonde Administrative #	Calibration Date	Delta Base TDG	Delta Press TDG	Delta Temp
1				
	3/27/00	-2	-2	
	4/ 4/00	0	1	
	4/18/00	1	1	0.10
	5/ 4/00	-1	-1	0.10
	5/22/00	1	2	
	6/12/00	-3	-3	0.10
	6/29/00	1	1	
	6/29/00	1	1	0.10
	7/17/00	-2	-1	0.10
	8/ 7/00	1	1	
	8/30/00	0	0	0.10
2				
	4/17/00	4	4	0.00
	5/ 3/00	-1	-1	0.00
	5/18/00	2	2	0.10
	6/ 5/00	0	1	0.00
	6/26/00	0	-1	0.10
	7/12/00	1	1	0.10
	7/27/00	0	0	0.10
	8/14/00	0	0	0.10
	9/ 5/00	0	-1	
	9/19/00	0	0	0.00
3				
	4/10/00	1	2	
	4/20/00	1	1	0.10
	5/ 8/00	-2	-2	0.00
	5/30/00	1	2	0.00
	6/14/00	0	0	

Sonde Administrative #	Calibration Date	Delta Base TDG	Delta Press TDG	Delta Temp
	6/29/00	2	3	0.00
	7/17/00	-2	-2	0.00
	8/ 7/00	0	0	
	9/ 7/00	0	0	0.00
5				
	3/29/00	0	0	
	4/17/00	1	1	0.00
	5/ 4/00	-1	-1	0.00
	5/22/00	2	2	
	6/12/00	0	0	0.00
	6/29/00	-1	-1	0.00
	7/13/00	0	0	0.00
	7/30/00	0	0	0.00
	8/21/00	-1	-1	0.10
6				
	5/ 3/00	-2	-2	0.00
	5/18/00	2	2	0.00
7				
	3/13/00	0	0	
	4/ 3/00	0	1	
	4/20/00	1	1	0.10
	5/ 8/00	-3	-3	0.00
	5/30/00	4	4	0.00
	6/14/00	0	0	
	6/15/00	0	0	
	7/ 5/00	-1	0	-0.10
	7/24/00	0	0	0.10
	8/10/00	0	0	0.00
	8/22/00	0	0	
	9/14/00	0	0	
	9/21/00	0	0	0.10

Sonde Administrative #	Calibration Date	Delta Base TDG	Delta Press TDG	Delta Temp
8				
	4/10/00	1	2	
	5/ 1/00	0	0	0.10
	5/17/00	-1	-1	
	6/ 1/00	2	1	0.00
	6/19/00	0	0	0.00
	7/10/00	0	0	0.10
	7/26/00	-1	-1	0.00
	8/10/00	0	0	
	8/24/00	1	1	
	9/ 8/00	0	0	0.00
9				
	3/13/00	0	0	
	3/29/00	-2	0	
	4/ 6/00	0	0	0.00
	4/24/00	0	0	
10				
	3/27/00	1	-5	
	4/ 6/00	-1	0	0.10
	4/24/00	1	1	
	5/31/00	0	1	0.00
	6/15/00	0	0	0.00
	7/ 5/00	-1	-1	0.00
	7/24/00	-1	-1	0.00
	8/10/00	-1	1	0.00
	8/23/00	2	2	0.00
	9/ 8/00	0	0	
	9/19/00	0	0	0.00
11				
	3/13/00	0	0	
	3/29/00	0	2	

Sonde Administrative #	Calibration Date	Delta Base TDG	Delta Press TDG	Delta Temp
	4/10/00	1	1	
	5/ 1/00	0	0	0.00
	5/17/00	0	0	0.10
	6/ 5/00	1	1	0.10
	6/26/00	-1	-1	0.00
	7/12/00	1	2	-0.10
	7/27/00	0	0	0.10
	8/14/00	-1	-1	0.00
	9/ 5/00	0	-1	0.10
13				
	5/ 8/00	-5	0	0.00
	5/30/00	1	3	0.00
	6/15/00	1	0	
	6/30/00	0	0	0.00
	7/17/00	0	0	-0.10
	8/ 7/00	1	1	
	8/30/00	0	0	
14				
	3/27/00	1	1	
	4/ 6/00	0	-3	0.10
	4/24/00	3	3	
	6/12/00	1	1	
	7/ 5/00	0	0	0.00
	7/24/00	1	1	0.00
	8/ 9/00	0	0	-0.10
	8/22/00	1	1	
	9/ 8/00	0	0	0.10
15				
	5/ 1/00	5	9	0.10
	5/17/00	0	1	0.00
	6/ 5/00	0	0	0.10

Sonde Administrative #	Calibration Date	Delta Base TDG	Delta Press TDG	Delta Temp
	6/26/00	-2	-1	0.00
16				
	4/17/00	0	2	0.10
	5/ 3/00	-2	-2	0.10
	5/15/00	2	1	0.00
	5/19/00	1	1	
	6/12/00	2	2	0.10
	6/29/00	0	0	0.00
	7/17/00	1	1	0.10
	8/ 7/00	0	0	-0.10
	8/22/00	0	0	
	9/20/00	0	0	0.00
18				
	3/13/00	0	0	
	4/ 3/00	-1	0	
	4/18/00	0	0	0.10
	5/ 8/00	-1	-1	0.00
	5/30/00	2	2	0.00
	6/15/00	0	-1	
	7/ 5/00	-3	-2	0.00
	7/24/00	3	2	
20				
	3/14/00	1	1	
	4/ 3/00	-1	1	
	5/15/00	-1	-2	
	5/15/00	0	0	
	6/ 1/00	1	1	0.00
	6/19/00	1	0	0.00
	7/10/00	0	1	0.00
	7/26/00	-1	0	0.00
	8/10/00	1	1	0.00

Sonde Administrative #	Calibration Date	Delta Base TDG	Delta Press TDG	Delta Temp
	8/30/00	0	0	0.00
	9/18/00	-1	-1	0.00
21				
	5/15/00	2	2	0.00
	5/31/00	0	1	0.00
	6/15/00	0	0	0.00
	7/ 9/00	0	0	0.00
	7/11/00	0	0	
	7/27/00	1	1	0.10
	8/14/00	0	0	0.10
	9/ 5/00	0	0	0.10
22				
	3/13/00	0	0	
	3/29/00	-1	1	
	4/ 4/00	0	0	
	4/18/00	1	1	0.10
	5/ 4/00	0	-1	0.00
	5/22/00	2	2	0.00
	6/12/00	0	0	0.10
	6/29/00	1	0	0.00
	7/13/00	1	0	0.00
	7/30/00	0	0	
	8/21/00	0	0	0.00
	9/ 8/00	0	0	
23				
	9/18/00	0	0	0.00
	10/ 6/00	0	0	0.00
25				
	3/14/00	1	1	
	4/ 3/00	-1	0	
	4/18/00	0	0	0.20

Sonde Administrative #	Calibration Date	Delta Base TDG	Delta Press TDG	Delta Temp
	5/ 4/00	0	0	0.10
	5/30/00	0	0	0.10
	6/14/00	1	0	
	7/ 9/00	-1	0	0.00
	7/26/00	0	0	0.00
	8/10/00	1	0	0.10
	9/ 5/00	0	0	0.20
26				
	3/27/00	1	1	
	4/ 6/00	-1	0	0.10
	4/24/00	0	0	
	5/15/00	1	0	0.20
	5/31/00	0	1	
	6/ 1/00	0	1	0.10
	6/19/00	0	0	0.10
	7/10/00	0	0	0.10
	7/26/00	-1	-1	0.00
	8/14/00	-1	0	0.30
	9/ 5/00	0	0	0.10
27				
	3/14/00	0	0	
	4/ 3/00	0	1	
	4/20/00	2	2	0.20
	5/15/00	2	3	0.10
	5/31/00	1	2	0.10
	6/26/00	0	0	0.20
	7/12/00	1	1	0.00
	7/30/00	0	0	0.00
	8/21/00	-2	-1	0.00
	9/14/00	0	0	
	10/ 2/00	0	0	0.20

Sonde Administrative #	Calibration Date	Delta Base TDG	Delta Press TDG	Delta Temp
28				
	3/29/00	-2	0	
	4/10/00	1	1	
	5/ 1/00	0	0	0.10
	5/16/00	0	0	0.10
	6/ 5/00	2	2	0.20
	6/26/00	-1	-2	0.00
	7/13/00	1	0	0.00
	7/30/00	0	0	0.00
	8/21/00	0	0	0.10
	9/18/00	0	0	-0.10
	10/ 6/00	0	0	0.00

APPENDIX E

STATION-SPECIFIC DATA

Station Specific Data

Station Identification	Deployment Date	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
ANQW					
	4/11/00	11	6	-7	-0.09
	4/18/00	16	1	2	0.05
	4/26/00	10	11	0	0.05
	5/ 9/00	18	10	-1	-0.01
	5/23/00	1	18	0	0.06
	6/ 6/00	15	1	10	-0.05
	6/21/00	26	15	-7	0.04
	7/ 6/00	7	26	-4	0.06
	7/19/00	16	7	-1	0.08
	7/30/00	27	16		
	8/16/00	26	27	-1	-0.10
	8/30/00	20	26	0	-0.05
	9/14/00	7	20	4	0.09
DWQI					
	3/16/00	25	26	0	0.03
	3/31/00	5	25	-2	-0.20
	4/11/00	8	5	3	0.12
	4/25/00	9	8	1	-0.13
	4/26/00	14	9	2	0.10
	5/ 9/00	3	14	-1	-0.09
	5/23/00	22	3	1	0.04
	6/ 6/00	2	22	3	0.01
	6/20/00	21	2	-5	0.00
	7/ 6/00	18	21	0	0.01
	7/18/00	1	18	0	-0.03
	7/31/00	22	1	1	0.02
	8/15/00	2	22		
	8/30/00	1	2	0	-0.04
	9/14/00	27	1	4	0.02
	9/21/00	7	27	0	-0.04

Station Identification	Deployment Date	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
IDSW					
	3/15/00	18	1	6	-0.07
	3/29/00	9	18	3	-0.11
	4/ 4/00	20	9	2	0.06
	4/19/00	5	20	0	-0.03
	5/17/00	20	19	2	0.06
	6/ 1/00	26	19	-4	-0.10
	6/14/00	7	19	1	0.11
	6/29/00	1	19	1	0.02
	7/12/00	21	19	-1	0.09
	7/27/00	25	19		
	8/ 9/00	16	25	1	-0.13
	8/22/00	22	16	0	0.01
	9/ 8/00	10	22	3	0.00
	9/19/00	20	10	0	-0.01
IHR					
	3/15/00	7	10	-1	-0.01
	3/30/00	22	7	-3	0.00
	4/ 4/00	7	22	2	-0.02
	4/19/00	25	7	1	0.01
	5/ 3/00	16	25	0	0.00
	5/17/00	28	16	-1	0.08
	6/ 1/00	21	28	1	-0.10
	6/14/00	14	21	0	0.00
	6/29/00	5	14	1	-0.11
	7/12/00	21	5	-1	0.01
	7/27/00	20	21	0	0.05
	8/ 9/00	14	20	7	0.14
	8/22/00	28	14	-5	0.07
	9/ 8/00	22	28	-2	-0.06
	9/19/00	23	22	-4	-0.06
LEWI					
	4/11/00	28	16	-1	0.16
	4/26/00	26	28	6	-0.06

Station Identification	Deployment Date	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
	5/ 9/00	13	26	0	-0.10
	5/24/00	5	13	2	0.03
	6/ 7/00	28	5	0	0.10
	6/20/00	20	28	1	-0.03
	7/ 6/00	10	20	0	-0.09
	7/18/00	13	10	-1	-0.09
	7/30/00	5	13	0	0.05
	8/16/00	21	5	0	0.00
LGNW					
	3/16/00	20	14	5	-0.04
	3/31/00	11	20	0	0.00
	4/ 7/00	14	11	-1	0.04
	4/21/00	7	14	2	0.00
	5/ 5/00	1	7	-2	-0.01
	5/19/00	2	1	1	0.00
	6/ 2/00	27	2	3	0.02
	6/16/00	10	27	6	0.02
	6/30/00	16	10	0	0.09
	7/14/00	27	16	0	-0.04
	7/28/00	26	27	1	-0.03
	8/11/00	20	26	0	0.00
	8/23/00	14	20	0	0.04
	9/ 7/00	26	14	-1	-0.02
LGS					
	4/ 7/00	10	3	0	-0.10
	4/21/00	18	10	1	-0.08
	5/ 5/00	25	18	-1	0.07
	5/19/00	15	25	5	-0.05
	6/ 2/00	20	15		0.04
	6/16/00	18	20	1	-0.01
	6/30/00	13	18	3	-0.02
	7/14/00	28	13	0	-0.12
	7/28/00	21	28	0	-0.05
	8/23/00	10	19	0	-0.03

Station Identification	Deployment Date	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
	9/ 7/00	3	10	0	-0.04
LGSW					
	4/ 7/00	26	8	-3	-0.04
	4/21/00	3	26	-1	-0.06
	5/ 5/00	5	3	-1	-0.01
	5/19/00	11	5	14	0.03
	6/ 2/00	8	11	2	0.11
	6/16/00	13	8	-1	-0.15
	6/30/00	3	13	2	0.05
	7/14/00	5	3	0	-0.03
	7/28/00	11	5	0	0.03
	8/11/00	8	11	0	0.01
	8/23/00	7	8	0	-0.04
	9/ 7/00	16	7	1	-0.02
LMN					
	4/10/00	27	2	0	0.03
	4/19/00	22	27	2	-0.01
	5/ 4/00	6	22	3	-0.10
	5/18/00	20	6	3	0.07
	6/ 1/00	18	20	3	0.02
	6/15/00	3	18	2	-0.02
	6/29/00	22	3	0	0.00
	7/13/00	2	22	0	0.04
	8/10/00	10	19	0	0.00
	8/22/00	27	10	0	-0.11
	9/ 8/00	8	27	0	0.02
LMNW					
	4/10/00	3	19		
	4/19/00	1	3	1	0.08
	5/ 4/00	2	1	0	0.05
	5/18/00	8	2	4	0.05
	5/31/00	10	8	6	-0.02
	6/15/00	25	10	-1	0.08
	6/29/00	28	25	1	0.02

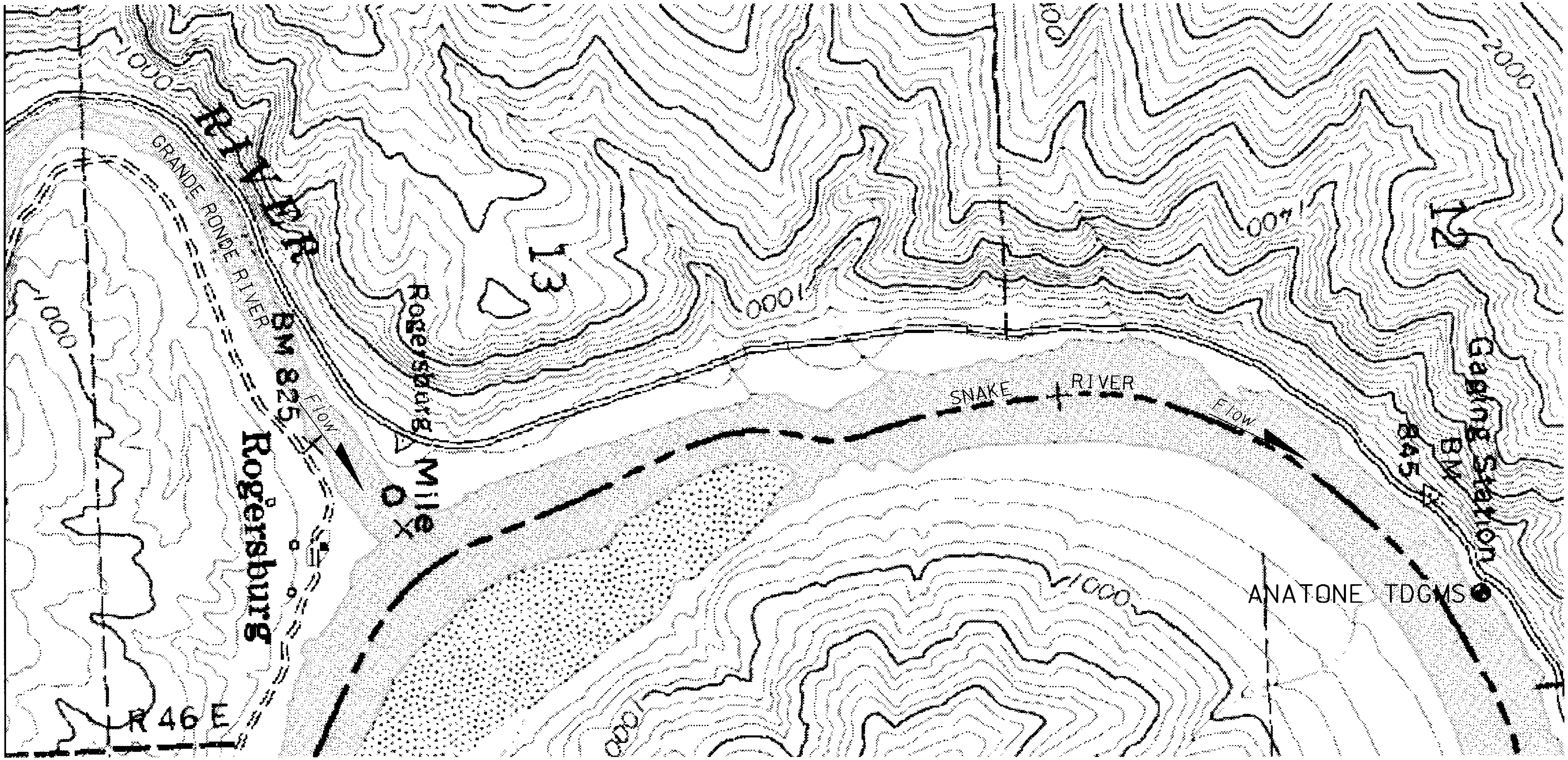
Station Identification	Deployment Date	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
	7/13/00	11	28	6	0.00
	7/27/00	8	11	-1	0.06
	8/10/00	7	8	0	0.02
	8/22/00	5	7	1	-0.15
	9/ 8/00	14	23	0	0.08
LWG					
	3/16/00	27	5	0	0.05
	3/31/00	28	27	1	-0.11
	4/ 7/00	9	28	0	-0.10
	4/21/00	27	9	2	0.11
	5/ 5/00	22	27	-4	-0.01
	5/19/00	6	22	3	-0.10
	6/ 2/00	26	6	-1	0.15
	6/16/00	7	26	-3	-0.07
	6/30/00	1	7	0	0.00
	7/14/00	22	1	0	-0.02
	7/28/00	2	22	0	-0.02
	8/11/00	25	2	0	-0.05
	8/23/00	16	25	2	-0.02
MCPW					
	3/14/00	9	25		
	3/28/00	26	9	-1	0.05
	4/ 5/00	25	26	1	-0.02
	5/ 2/00	15	19	3	0.05
	5/16/00	26	15	-4	0.03
	5/31/00	7	26	-2	0.01
	6/13/00	5	7	-2	-0.06
	6/27/00	11	5	-4	0.04
	7/11/00	26	11	-5	0.02
	7/25/00	14	26	-4	0.01
	8/ 9/00	3	14	0	-0.07
	9/ 6/00	2	3	-1	0.02
	9/19/00	28	2	0	0.02
	10/ 6/00	27	28	0	-0.07

Station Identification	Deployment Date	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
MCQO					
	3/14/00	22	27	-4	0.00
	3/28/00	14	22	-2	0.00
	4/ 5/00	22	14	-6	-0.02
	5/ 2/00	28	6	-2	0.15
	5/16/00	27	28	0	-0.14
	5/31/00	25	27	-4	0.04
	6/13/00	22	25	-1	-0.03
	6/27/00	27	22	0	-0.17
	7/11/00	8	27	-4	0.03
	7/25/00	7	8	0	-0.01
	8/ 9/00	13	7	1	-0.11
	9/ 6/00	11	19	-3	0.06
	9/19/00	10	11	0	0.06
	10/ 6/00	28	10	-2	0.10
MCQW					
	3/14/00	11	20	0	0.00
	3/28/00	10	11	1	0.02
	4/ 4/00	1	10	-4	-0.08
	5/ 2/00	11	16	1	-0.05
	5/16/00	21	11	-3	0.04
	5/31/00	3	21	1	-0.07
	6/13/00	1	3	-5	0.03
	6/27/00	2	1	1	0.12
	7/11/00	20	2	0	-0.21
	7/25/00	10	20	-3	-0.02
	8/ 9/00	1	10	-1	-0.02
	8/24/00	8	1	0	0.01
	9/ 6/00	21	8	0	-0.01
	9/19/00	2	21	-1	-0.04
	10/ 6/00	23	2	0	0.01
PAQW					
	3/28/00	1	28	0	-0.10
	4/ 4/00	18	1	4	-0.06

Station Identification	Deployment Date	QA/QC Sonde	In-Place Sonde	Delta TDG	Delta Temp
	4/18/00	2	18	0	0.06
	5/ 2/00	8	2	0	0.01
	5/17/00	16	8	-1	0.00
	5/31/00	13	10	-1	-0.10
	6/14/00	16	13	-2	0.12
	6/28/00	15	16	4	-0.06
	7/11/00	25	15		
	7/26/00	18	25	0	-0.12
	9/ 6/00	25	17	0	0.02
PEKI					
	5/ 9/00	7	20	-4	0.07
	5/23/00	16	7	3	0.02
	6/16/00	11	16	3	-0.04
	6/20/00	8	11	-2	0.05
	7/ 6/00	14	8	-1	-0.01
	7/18/00	3	14	1	-0.06
	7/31/00	28	3	0	0.13
	8/15/00	11	28	1	-0.11
	8/30/00	13	11	0	0.08

APPENDIX F

MAPS



N

LEGEND

⊕ STATION LOCATION

600 0 600

SCALE IN FEET

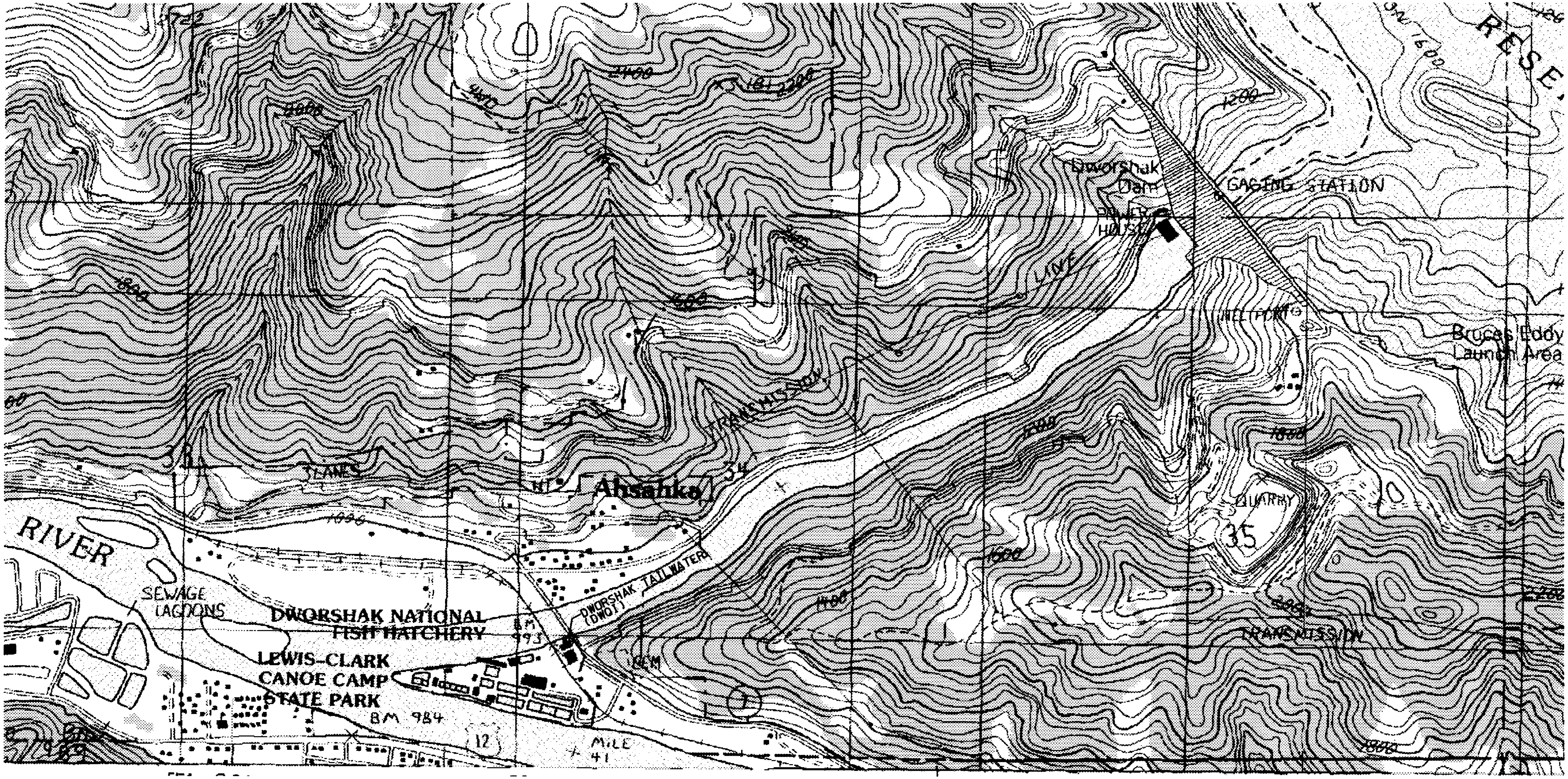
PLATE 1

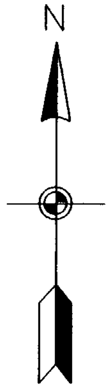
SNAKE RIVER BASIN

U.S.G.S. GAGING STATION LOCATION SNAKE RIVER NEAR ANATONE, WASHINGTON

U.S. ARMY ENGINEER DISTRICT
WALLA WALLA DISTRICT - HYDROLOGY SECTION

DESIGNED	DRAWN	DATE
HALL	SLACK	MAY 2000





LEGEND
⊕ STATION LOCATION
• PROBE LOCATION

1000 0 1000
SCALE IN FEET

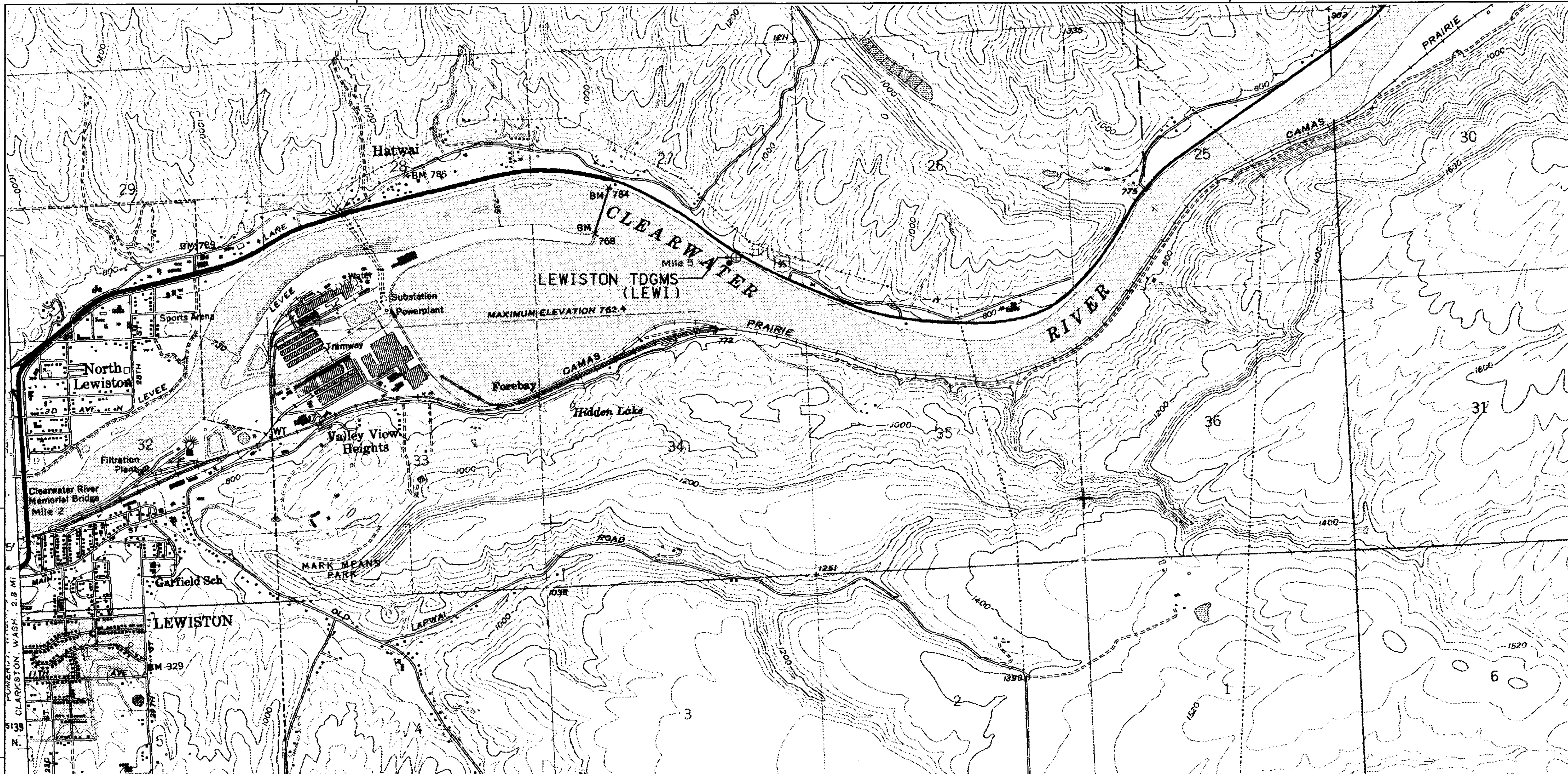
PLATE 2

DWORSHAK DAM
CLEARWATER RIVER, IDAHO
VICINITY OF AHSAHKA, IDAHO

TOTAL DISSOLVED GAS MONITORING SYSTEM STATION LOCATIONS

U.S. ARMY ENGINEER DISTRICT
WALLA WALLA DISTRICT - HYDROLOGY SECTION

DESIGNED	DRAWN	DATE
G. SLACK	G. SLACK	OCT. 2000



N

NOTE:

1. THE POSITION OF THE LEWISTON TDGMS STATION IS APPROXIMATE THE TIME OF MAPPING. IT IS BELIEVED TO BE WITHIN +/- 500 FEET FROM THE ACTUAL LOCATION.

LEGEND

⊕ STATION LOCATION
• PROBE LOCATION

2000 0 2000
SCALE IN FEET

PLATE 3

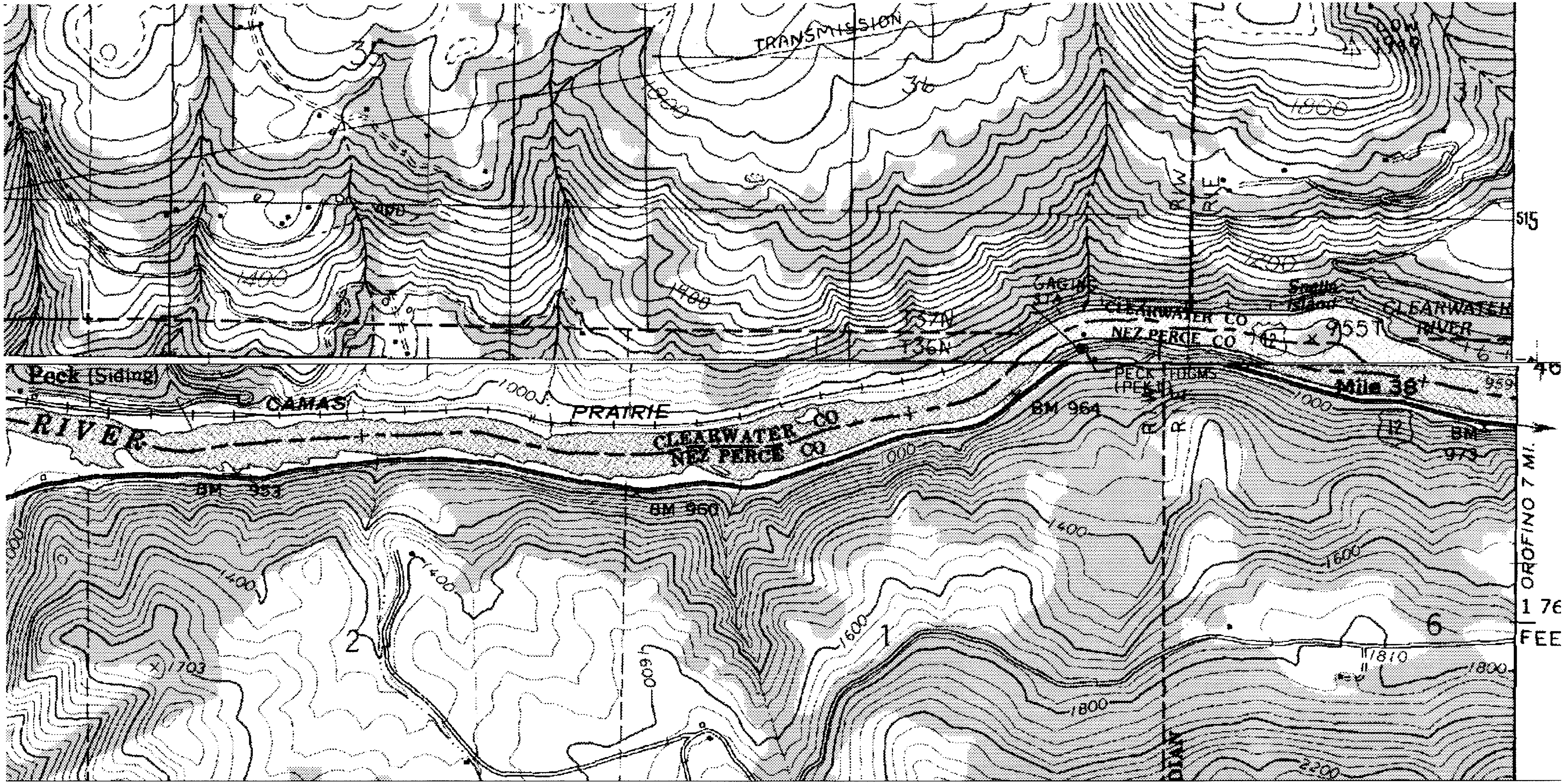
CLEARWATER RIVER, IDAHO
VICINITY OF LEWISTON, IDAHO
LEWISTON TDGMS STATION

TOTAL DISSOLVED GAS MONITORING SYSTEM STATION LOCATIONS

U.S. ARMY ENGINEER DISTRICT

WALLA WALLA DISTRICT - HYDROLOGY SECTION

DESIGNED	DRAWN	DATE
G. SLACK	G. SLACK	OCT 2000



N

LEGEND

⊕ STATION LOCATION

• PROBE LOCATION

1000 0 1000

SCALE IN FEET

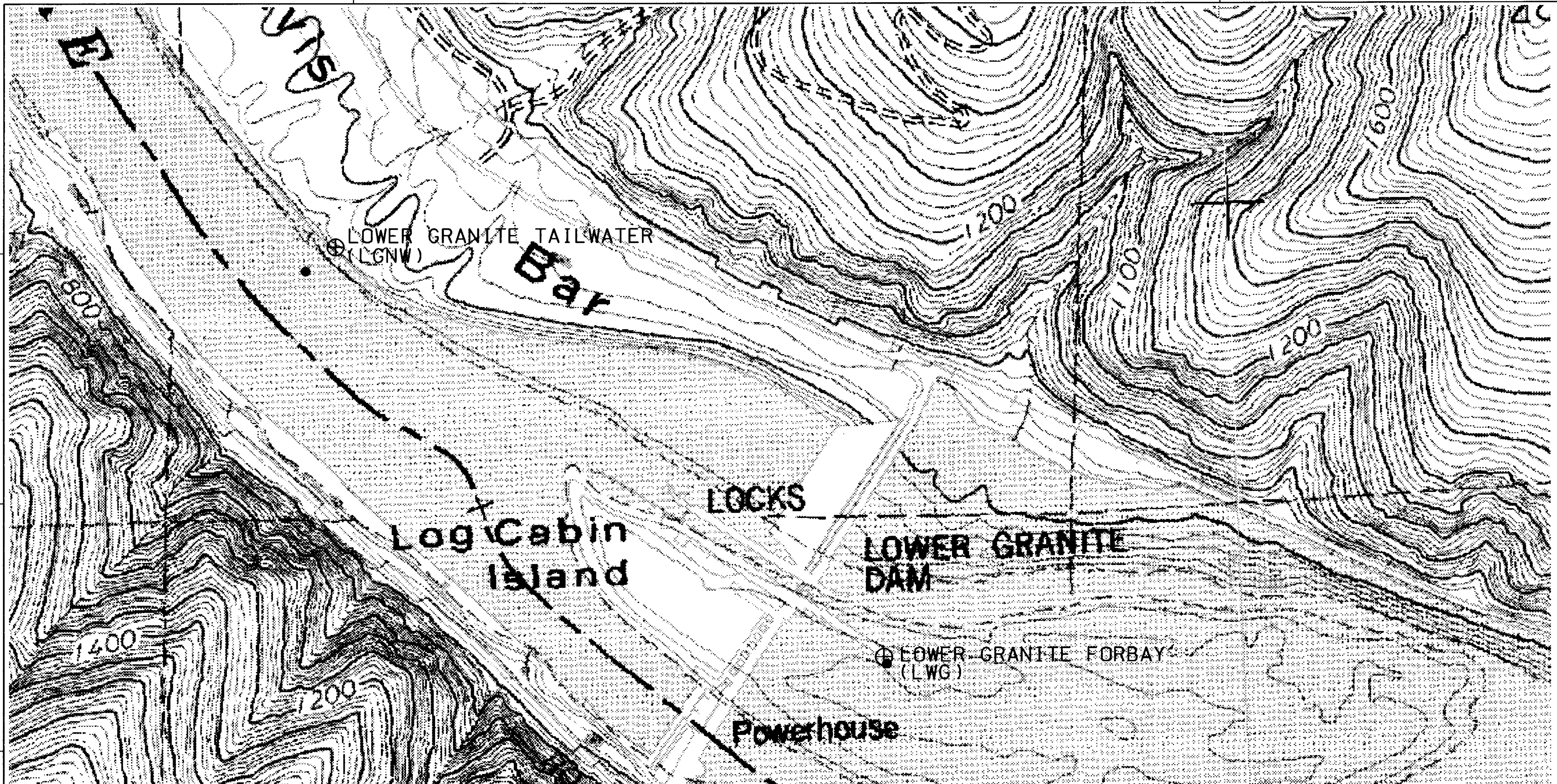
PLATE 4

CLEARWATER RIVER, IDAHO
VICINITY OF PECK, IDAHO
PECK TDGMS STATION

TOTAL DISSOLVED GAS MONITORING
SYSTEM STATION LOCATIONS

U.S. ARMY ENGINEER DISTRICT
WALLA WALLA DISTRICT - HYDROLOGY SECTION

DESIGNED	DRAWN	DATE
G. SLACK	G. SLACK	OCT. 2000



LEGEND

- ⊕ STATION LOCATION
- ● PROBE LOCATION

600 0 600

SCALE IN FEET

PLATE 5

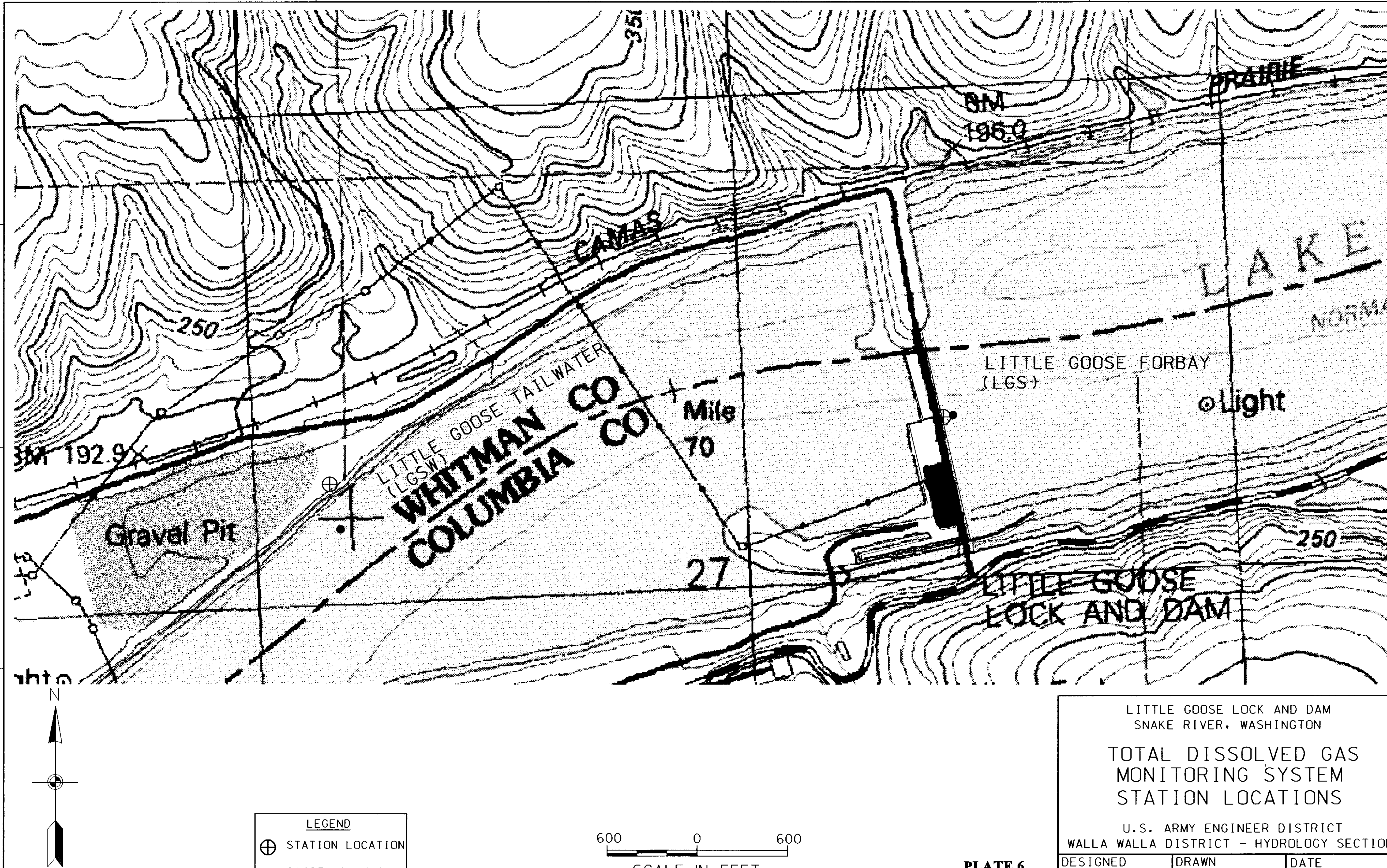
LOWER GRANITE LOCK AND DAM
SNAKE RIVER, WASHINGTON

TOTAL DISSOLVED GAS
MONITORING SYSTEM
STATION LOCATIONS

U.S. ARMY ENGINEER DISTRICT
WALLA WALLA DISTRICT - HYDROLOGY SECTION

DESIGNED	DRAWN	DATE
HALL	SLACK	MAY 2000

MAP 5



LEGEND

⊕ STATION LOCATION

● PROBE LOCATION

PLATE 6

LITTLE GOOSE LOCK AND DAM
SNAKE RIVER, WASHINGTON

TOTAL DISSOLVED GAS
MONITORING SYSTEM
STATION LOCATIONS

U.S. ARMY ENGINEER DISTRICT
WALLA WALLA DISTRICT - HYDROLOGY SECTION

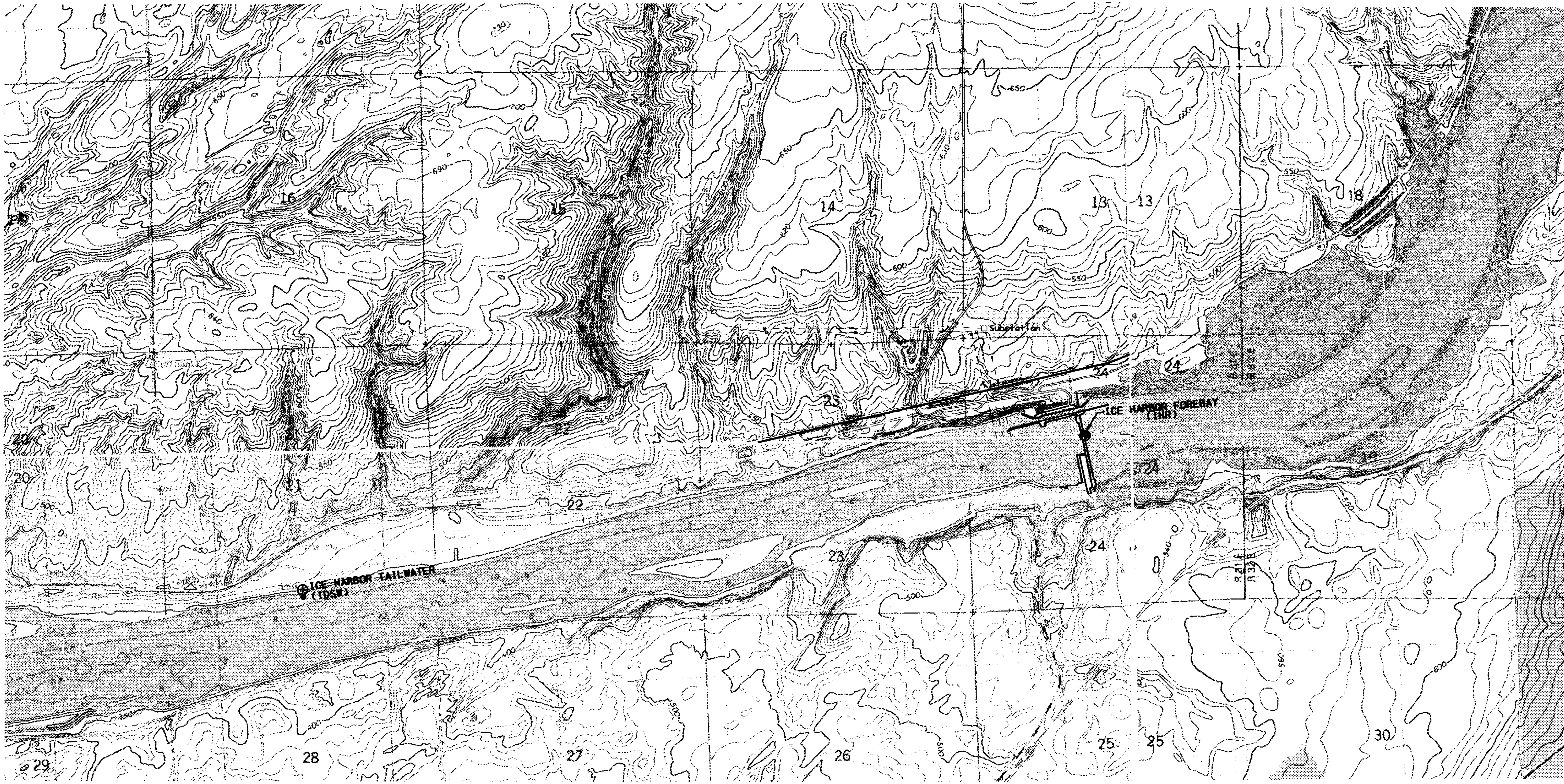
DESIGNED	DRAWN	DATE
HALL	SLACK	MAY 2000

MAP 4

CORPS OF ENGINEERS

SAFETY PAYS

U. S. ARMY



N

LEGEND

⊕ STATION LOCATION
• PROBE LOCATION

2000 0 2000
SCALE IN FEET

PLATE 7

ICE HARBOR LOCK AND DAM
SNAKE RIVER, WASHINGTON

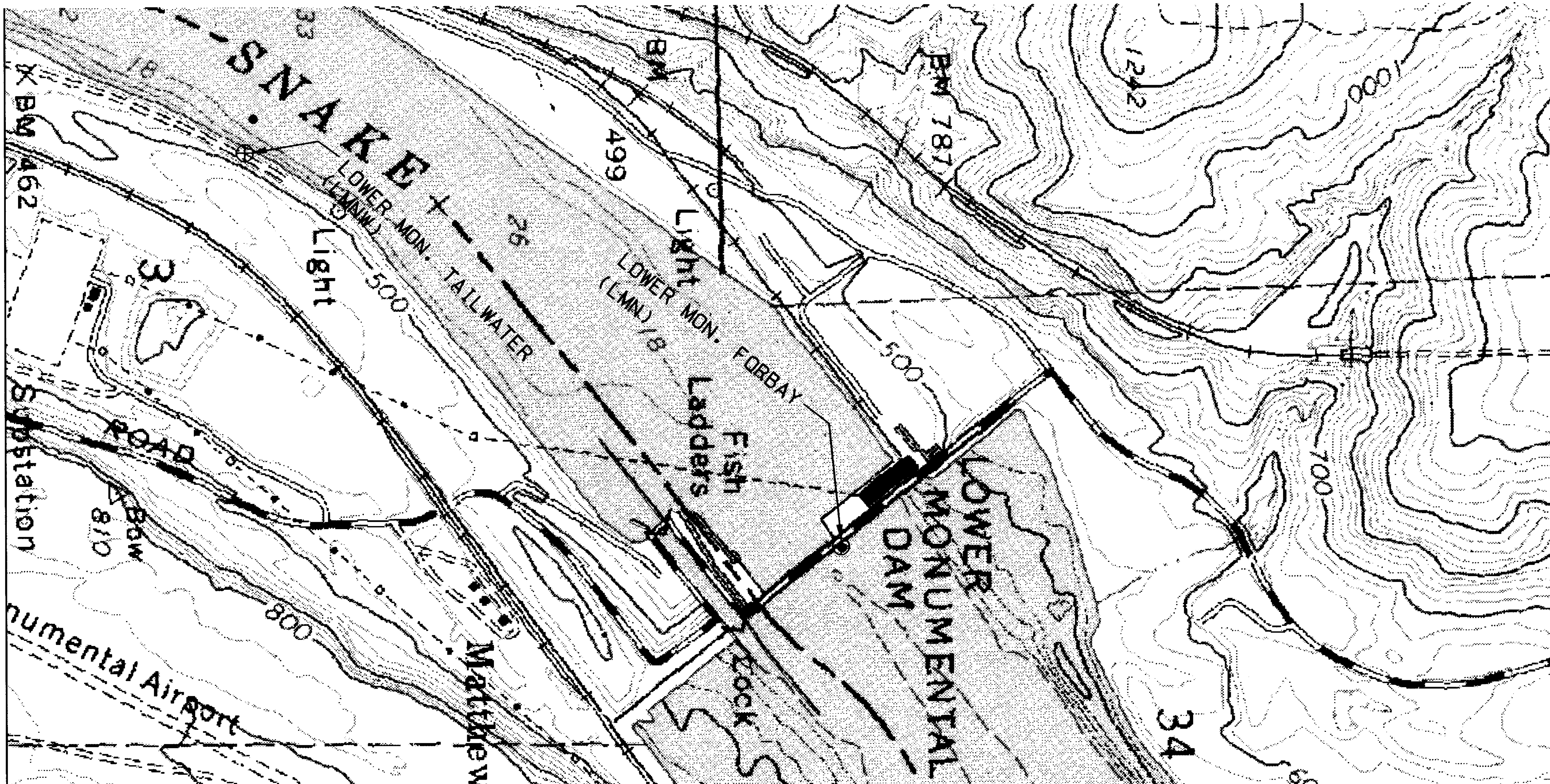
TOTAL DISSOLVED GAS MONITORING SYSTEM STATION LOCATIONS

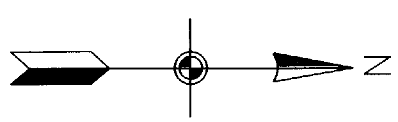
U.S. ARMY ENGINEER DISTRICT
WALLA WALLA DISTRICT - HYDROLOGY SECTION

DESIGNED	DRAWN	DATE
G.SLACK	G. SLACK	OCT 2000

VALUE ENGINEERING PAYS

MAP 2





LEGEND
- ⊕ STATION LOCATION
- • PROBE LOCATION

600 0 600
SCALE IN FEET

PLATE 8

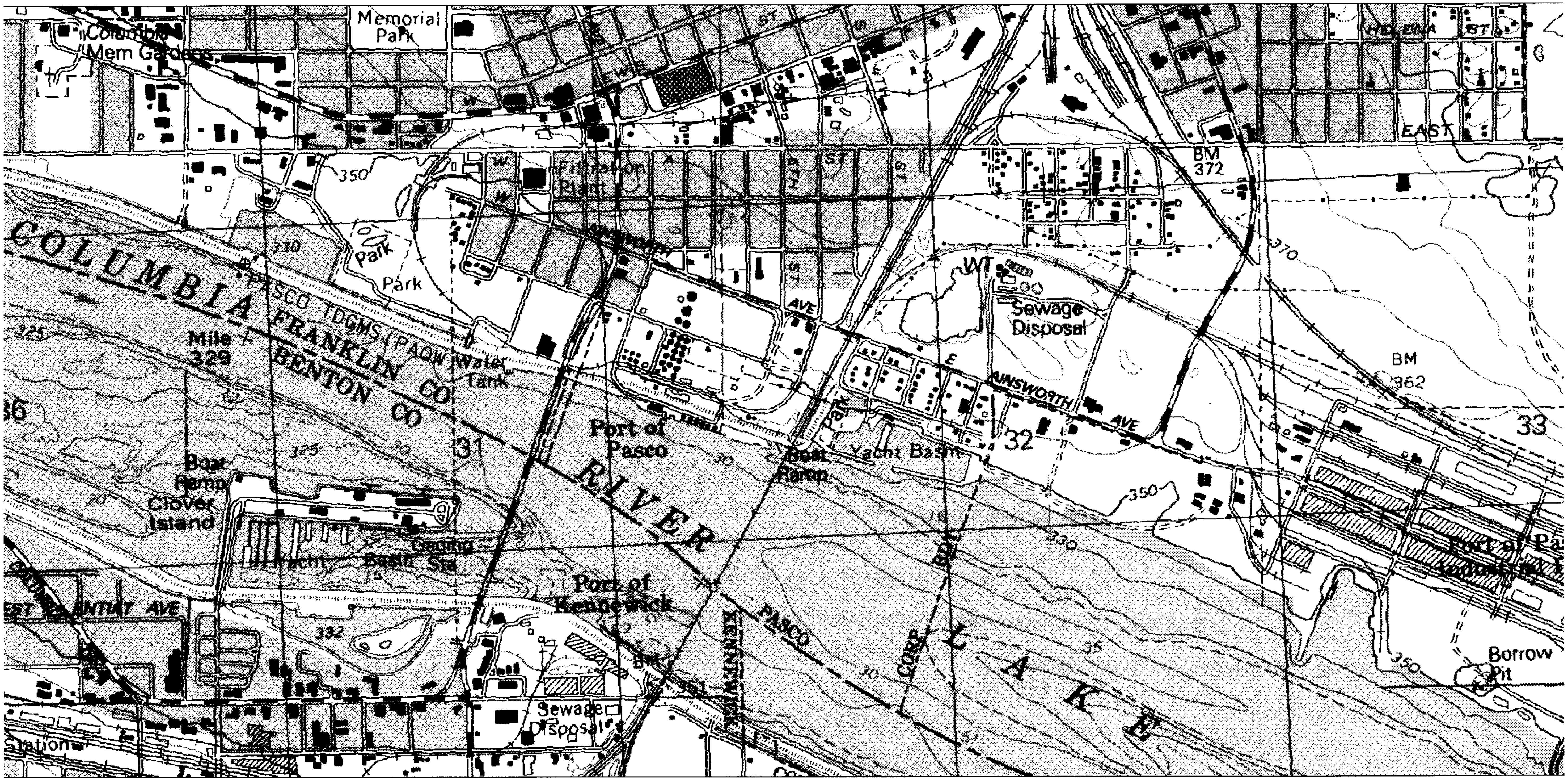
LOWER MONUMENTAL LOCK AND DAM
SNAKE RIVER, WASHINGTON

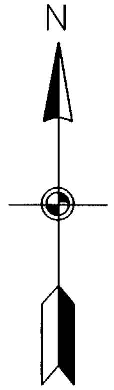
TOTAL DISSOLVED GAS MONITORING SYSTEM STATION LOCATIONS

U.S. ARMY ENGINEER DISTRICT
WALLA WALLA DISTRICT - HYDROLOGY SECTION

DESIGNED	DRAWN	DATE
HALL	SLACK	MAY 2000

MAP 3





LEGEND

⊕ STATION LOCATION

• PROBE LOCATION

1000 0 1000

SCALE IN FEET

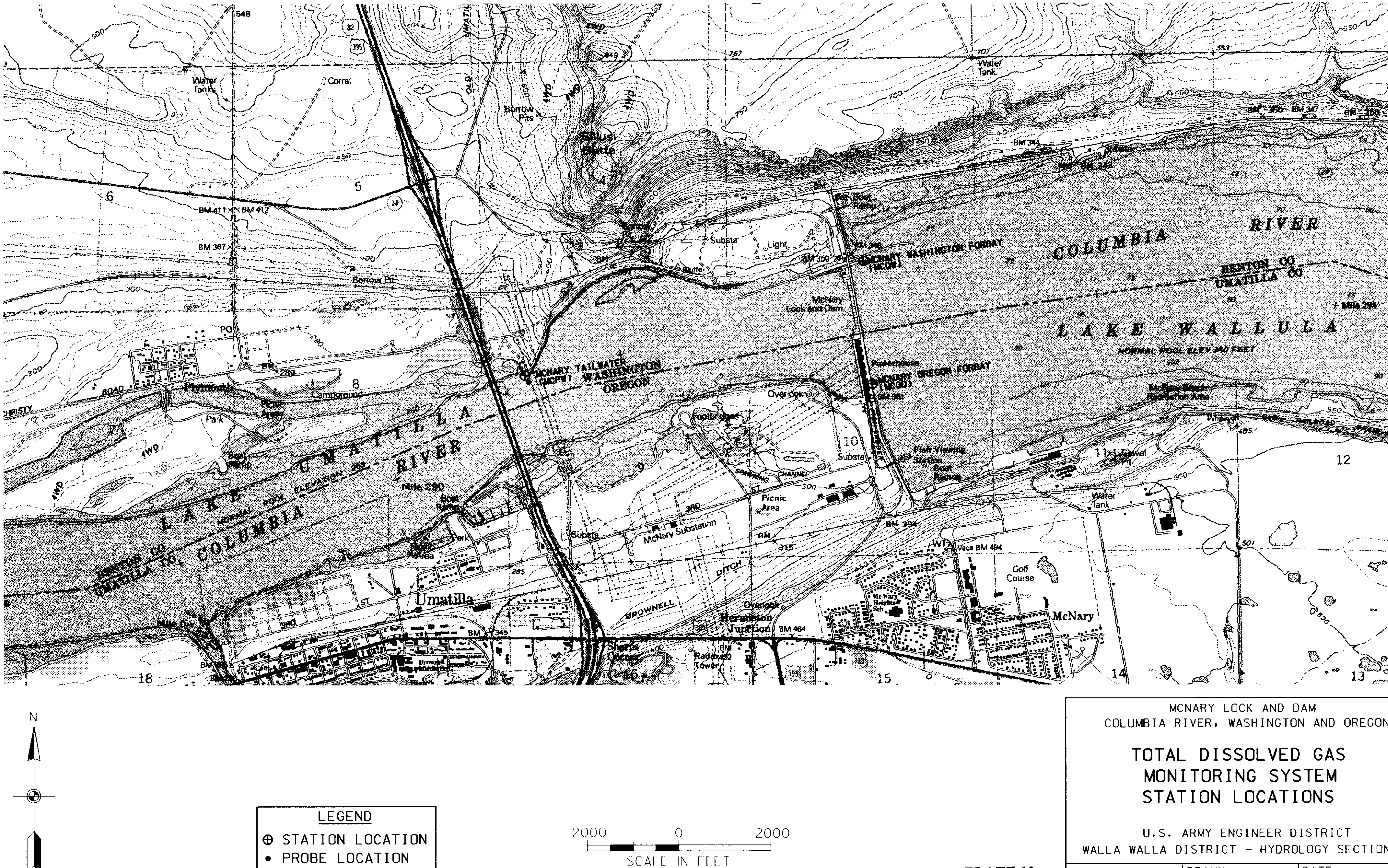
PLATE 9

COLUMBIA RIVER, WASHINGTON
VICINITY OF PASCO, WASHINGTON

TOTAL DISSOLVED GAS MONITORING SYSTEM STATION LOCATIONS

U.S. ARMY ENGINEER DISTRICT
WALLA WALLA DISTRICT - HYDROLOGY SECTION

DESIGNED	DRAWN	DATE
G. SLACK	G. SLACK	OCT. 2000



LEGEND

⊕ STATION LOCATION
• PROBE LOCATION

PLATE 10

MCNARY LOCK AND DAM
COLUMBIA RIVER, WASHINGTON AND OREGON

TOTAL DISSOLVED GAS MONITORING SYSTEM STATION LOCATIONS

U.S. ARMY ENGINEER DISTRICT
WALLA WALLA DISTRICT - HYDROLOGY SECTION

DESIGNED	DRAWN	DATE
G.SLACK	G. SLACK	OCT 2000